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VOL. XXXV. — No. 5. MAY 1958.

Monthly Bulletin of the International Railway Congress Association

(English Edition)

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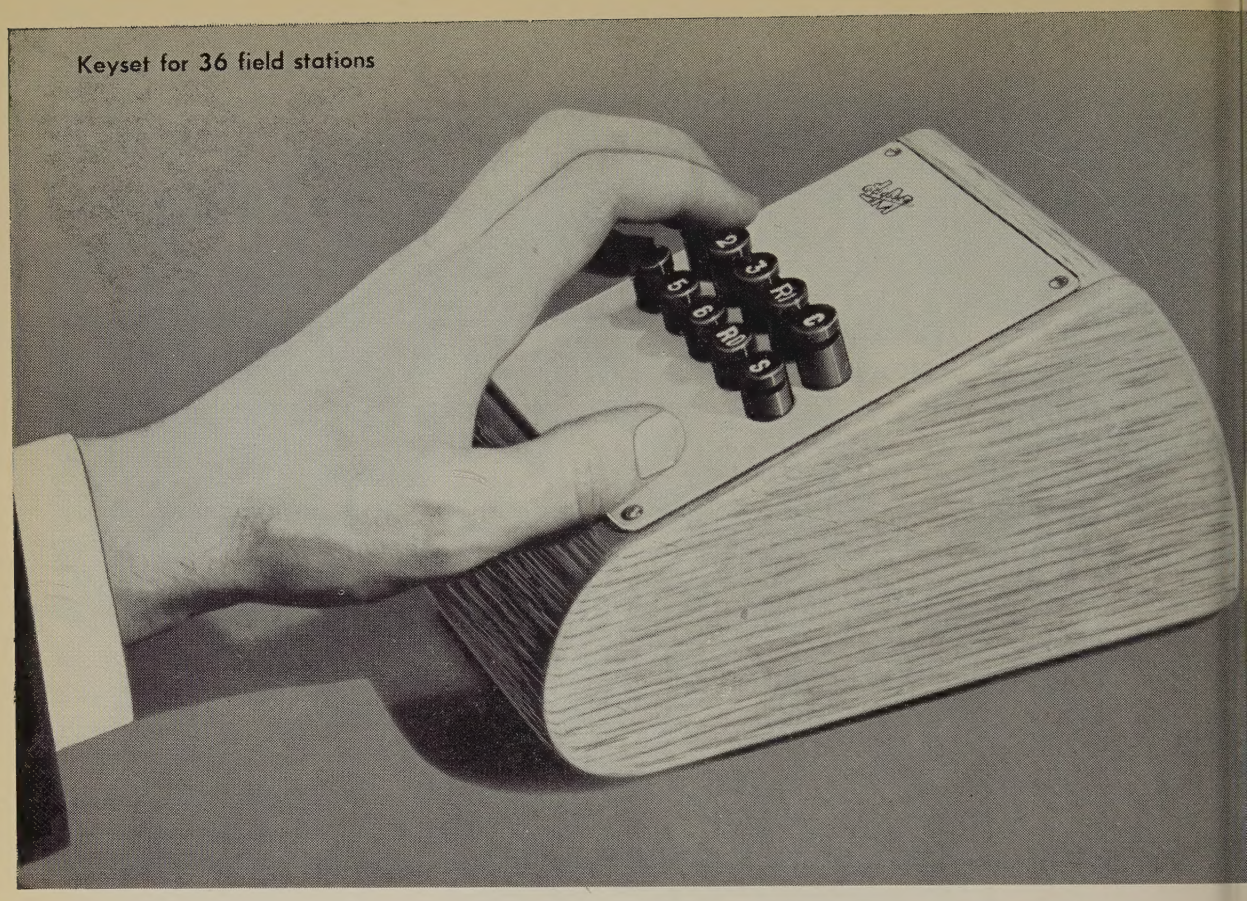

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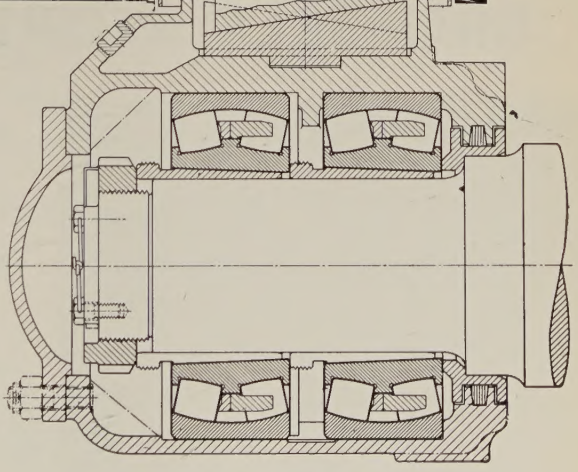

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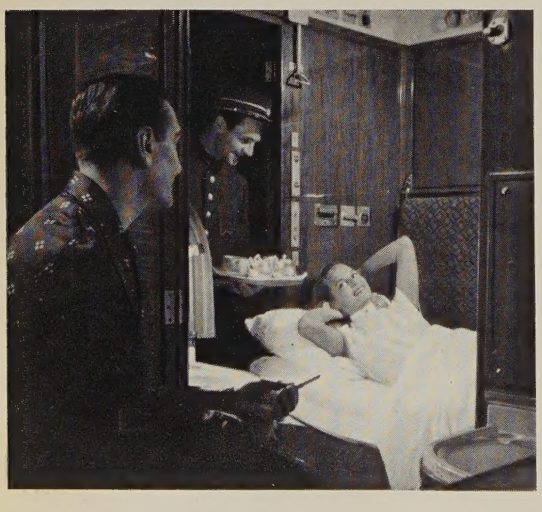

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TIME-TABLE

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8.43 a. m.	↓	Brussels M.	↑	9.15 p. m.

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Bulletin of the International Railway Congress Association

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MONTHLY BULLETIN

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Works in connection with railway matters, which are presented to the Permanent Commission are mentioned in the « Bulletin ». They are filed and placed in the library. If the Executive Committee deems it advisable they are made the subject of a special notice. Books and publications placed in the reading room may be consulted by any person in possession of an introduction delivered by a member of the Association.

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An edition in French is also published.

Vol. XXXV. — No. 5. May 1958.

BULLETIN
OF THE
INTERNATIONAL RAILWAY CONGRESS
ASSOCIATION
(ENGLISH EDITION)

[624]

INTERNATIONAL RAILWAY CONGRESS ASSOCIATION

17th. SESSION (MADRID, 1958).

QUESTION 1.

Problems presented by the ageing of bridges and viaducts. Long term effects of fatigue and corrosion in steel bridges and weathering of masonry.

Rational methods of maintenance of bridges.

Repair and strengthening.

REPORT

(America (North and South), Australia (Commonwealth of), Burma, Ceylon, Egypt, Western Germany, India, Irak, Iran, Republic of Ireland, Japan, Malaysia, New Zealand, Norway, Pakistan, South Africa, Sudan, Sweden, Union of Soviet Socialist Republics and the United Kingdom of Great Britain and Northern Ireland and dependent overseas territories),

by Fr. LEMMERHOLD,

Referent für Brückenangelegenheiten in der Hauptverwaltung der Deutschen Bundesbahn.

PREAMBLE.

The present report has been subdivided into the following four parts.

1. *General considerations* concerning the service life and the conservation of old railway bridges.

2. *Steel Bridges.*

   Carrying capacity, tests, damages, temporary measures, rust protection, repair, and strengthening.

3. *Bridges in Masonry and Concrete.*

   Damages, tests, waterproofing, ballast depth, repair, and strengthening.

4. *Inspection and Conservation of Bridges.*

The answers to a questionnaire containing 63 questions served as a basis for the elaboration of this report. The questionnaire was mailed to 35 railway administrations (English section). Five administrations stated that they are very interested in this matter, but that they are not in a position to answer the questions on account of lacking data and/or technical personnel. 14 administrations have not replied.

The undermentioned 16 administrations furnished partly extensive information :

1. Association of American Railroads . . . . A.A.R.

2. British Transport Commission	B.T.C.
3. London — Transport Railways	L.T.R.
4. Coras Iompair Eireann	C.I.E. (Eire).
5. Norske Statsbaner . .	Nor. R.
6. Statens Järnvägar . .	Swed. R.
7. Grängesberg-Oxelösunds Järnvägar	T.G.O.J.
8. Nigerian Railway Corporation	Nig. R.
9. East African Railways .	EAfr. R.
10. Rhodesia Railways . .	Rhod. R.
11. South African Railways.	SAfr. R.
12. Japanese National Railways	Jap. R.
13. Malayan Railway . . .	Mal. R.
14. Indian Government Railways	Ind. R.
15. Deutsche Bundesbahn .	D.B.
16. Österreichische Bundesbahn	Ö.B.B.

The summarizing of the — sometimes — very divergent data and views was difficult. As far as it was possible, the answers are shown in the form of tables.

Further difficulties were encountered on account of the different interpretation of technical terms. As example it should be mentioned that the term « casing » was misinterpreted. Consequently, the pertaining questions were left unanswered or they were uncomprehensible.

In spite of this — and thanks to the efforts made by 16 administrations — it was feasible to establish a quite complete report containing many new views and methods of general interest with regard to the problems dealt with.

1) General considerations.

1.11) When designing a new bridge, what estimates do you make for each type of structure, as regards the length of life in service that can reasonably be expected, taking into account all the factors which normally affect this life ?

When designing new steel, masonry, and concrete bridges, it is generally unusual to consider a definite service life, but bridges are constructed to give the longest possible life. Only in case of bridges which, for special reasons, must have a certain service life, e.g. makeshift solutions, or bridges located on lines giving access to areas with mineral resources the exploitation of which is limited in time, or bridges erected for strategical purposes, temporary wooden structures or bridges assembled from makeshift components are employed.

With regard to the type of construction to be selected all administrations agree that maximum service life can be expected if arched bridges using bricks, natural stones, and concrete — under the assumption that the latter has been carefully made — are erected.

The data given vary from :

80 years (Swedish State Rlys., Austrian Federal Rlys.,) to infinite (Norwegian State Rlys.).

The service life of steel bridges is generally expected to be 60 to 75 years and the same is true for structures consisting of steel encased in concrete.

Referring to reinforced concrete it should be noted that the experiences gained in this field are still insufficient. Consequently, it is not surprising that the estimates made are very different :

with 40 years A.A.R. (Association of American Railroads) ;

and 80 to 100 years (Nigerian Rlys., Irish Rlys., East African Rlys, Japanese Nat. Rlys., German Federal Rlys., Austrian Federal Rlys.).

The same is true for prestressed concrete structures for which, for obvious reasons, adequate experiences are nowhere available.

In case the estimate for the service life is *high* it has been doubtless assumed that

the latest technologies in making concrete have been used for the erection and construction.

The service life to be expected for wooden structures amounts uniformly:

to 15 years, if soft wood is employed, and 30 to 40 years, if hardwood is used.

1.12) Since the above life must be considered as the ideal, what is the actual length of life of bridges subdivided into types as above?

Obviously untoward incidents are not to be taken into account.

Under the condition that the useful life has to be considered as the service life actually attained it will be noted that there are deviations from the above quoted average values, i.e. in the sense of larger or smaller numbers than the average. For obvious reasons the useful life is only known for such structures which have become unserviceable on account of normal wear and tear. In many cases other factors were decisive, e.g. the fact that the type of vehicles worked over a bridge changed. Only a comparatively small number of bridges deteriorated so badly, due to corrosion, fatigue, and damaged stones, that they had to be renewed. A considerable number of railway lines has not yet reached an age that the wear of their structures had to be expected. It is unanimously agreed that, with a few exceptions only, steel bridges had to be strengthened or renewed by exchanging structural components due to increased loads (axle pressure and weight per meter) and higher speeds, and this in spite of the fact that the spans had reached a service life of hardly 60 years and were still sound.

The A.A.R. indicates that their oldest steel structures are 70 years old and that they are still in a good condition so that their life will be at least 100 years.

Contrary to steel bridges, ample experiences could be attained with regard to the useful life of arched bridges in masonry or concrete. The reason for this is that arched structures had not to be renewed or strengthened since they are capable to stand overloadings. In many cases where bridges were built from natural stones the original material is still in use though it is more than 100 years old (see table 1).

1.21) In your budget under what headings do you include the maintenance and renewal of bridges?

Is the amount allocated for this purpose based on the value of the bridges when new, on their present value or on their replacement cost? What is the total percentage compared with one or other of the above values? If you make use of other principles in your estimates, please state what these are.

The annual required amounts for bridge maintenance and renewals are determined, in nearly all cases, on account of the applications submitted by local offices. Furthermore, it can be stated that the determination of the amount necessary for maintenance works is uniformly assessed on account of empiric values attained during the last years. In Japan the determination is based on the year 1936, the year when the operation was most well balanced. In the majority of all cases the funds required for maintenance purposes are the sum of a great number of individual projects as a function of the works the execution of which is requested in the inspection reports established by field offices. The amounts required for maintenance purposes are frequently assessed by estimates. The entire amount is included in the budget and covered by current revenues.

At several administrations major amounts required for carrying out repair work are not covered out of revenues, but out of reserve funds. Generally, special estimates are established for the individual jobs which must be sanctioned from a financial and technical point of view. With some state-owned railways the necessary appro-

TABLE 1. — **Actually attained service life of bridges.**

	A.A.R.	*B.T.C.*	*L.T.R.*	*C.J.E. (Eire)*	*Nor.R.*	*Swed.R.*	*T.G.O.J.*	*Nig. R.*
1*a*. Arched bridges made from stones or	—	120	100 years and more	Many structures older than 100 years	90	100	70	No experience, bridges were in all cases changed or reinforced before reaching age limit
1*b*. Concrete. . . .	50	—	—		—	—	—	
2. Steel bridges . .	100	50/60	60/80		removed before reaching age limit	75-85	70 reinforced and removed before reaching age limit	
3. Structures made from rolled beams encased in concrete	—	75	—		—	—	—	
4. Reinforced concrete bridges . .	40/50	60	—		—	no experience	—	
5. Wooden bridges (hardwood) . .	60	—	—	—	—	—	—	

TABEL 1. — **Actually attained service life of bridges** *(continued)*.

	EAfr. R.	*Rhod. R.*	*SAfr. R.*	*Jap. R.*	*Mal. R.*	*Ind. R.*	*D.B.*	*Ö.B.B.*
1*a*. Arched bridges made from stones or	No figures given, bridges were reinforced or removed before reaching age limit	No figures given, bridges were reinforced or removed before reaching age limit	90	70	—	100	120	110
1*b*. Concrete			—	—	—	—	60	—
2. Steel bridges . .			75	55	50	60	60	60
3. Structures made from rolled beams encased in concrete			—	—	—	—	50-75	—
4. Reinforced concrete bridges . .			no experience	—	—	—	no experience	—
5. Wooden bridges (hardwood) . .			—	—	—	—	(*)	—

(*) All wooden structures have been removed.

priation of the funds must be made by the Parliament.

The depreciation rate — generally fixed with due consideration of the service life and the costs of remplacement — varies between 1.5 and 2 %.

The individual railways have reported the following details :

a) *Norwegian State Railways.*

The funds required for the renewal of steel bridges are fixed — under the assumption of a service life of 67 years — at a theoretical percentage of 1.5; the costs of replacement are taken as a basis. This theoretical percentage is generally not attained.

b) *Swedish State Railways.*

The new construction and complete reconstruction of a structure are considered as capital investment. 1.6 % of the replacement value are written off per annum.

c) *T.G.O.J.*

The repurchasing value is taken as a basis for the determination of the funds requisite for bridge maintenance and renewals. The overall percentage — fixed by legal stipulations — amounts to 1.75.

d) *Nigerian Railway.*

In the budget all maintenance expenditure is paid for out of revenue and all renewals are paid from capital. There is no renewals fund.

e) *South African Railways.*

Heavy repair work requiring replacement of members, extensive fettling-up work involving replacement of large numbers of loose or corroded rivets, the complete removal of all old paint and the subsequent application of new coats of approved paints fall under the heading « Heavy or Extraordinary Maintenance » and form the subject of separate estimates and authority to incur such expenditure. It still, however, is a charge against revenue, and must be provided for in the annual estimates so that the necessary appropriation of funds may be made by Parliament.

The strengthening of existing structures is regarded as an improvement and financed from the Administration's Betterment Fund which is maintained by appropriations from surplus revenues. Detailed estimates are prepared and Parlamentiary sanction for the specific work is necessary. That portion of the expenditure representing an increase in the capacity of the bridge is capitalized and the book value is adjusted accordingly.

f) *Japanese National Railways.*

Effective 1956 a method has been introduced according to which the General Manager decides on the outlay for the maintenance of bridges belonging to the Railway Operating Divisions under his control. As may be clear from the foregoing, the Japanese National Railways have no established principle or criteria for the budget appropriation for bridge maintenance as referred to in the questionnaire. Such state of practice in the assessment of the budget for maintenance of bridges is *not* considered *adequate,* and the Japanese National Railways are now making a study into this problem.

Funds for renewals are 90 % of the present values of bridges, divided by 40 years to be earmarked as a whole for each year from annual revenue. However, the funds to be expended actually are allocated in individual cases of requisition in an amount

deemed necessary by technical assessment.

g) *Indian State Railways.*

Maintenance costs are covered out of revenues and renewal cost out of the « Depreciation Reserve Fund ». The amount to be allocated for maintenance purposes is not related to a percentage, but it is based on cost and estimates for the preceding years, and which were established on account of technical inspections of the structures in question. The amount for renewals in the budget is related to the presently charged prices; this amount is credited to the « Depreciation Reserve Fund ».

h) *D.B.*

The annually required amounts for maintenance and renewals are based on scheduled maintenance and renewal jobs which, in turn, are determined as a percentage of the new value. Thus the theoretical rate for :

bridge maintenance is 0.46 %, while that for

bridge renewals is 1.17 %.

Owing to the fact that the new value equals the amount paid for the original purchase of the structure — corrected in accordance with the prices presently charged — additional cost will accrue in some cases.

Since the annually required overall amount to be spent for maintenance and renewals must be paid out of revenues (operating account) the amounts actually available during the recent years did *not* reach the scheduled amounts.

i) *Ö.B.B.*

The amounts expended during the preceding years serve as a basis for the assessment of the expenditures to be made for maintenance and renewal of bridges with due consideration of the increase in prices which occurred in the meantime. The amounts requested by the field offices must be adjusted to the possibilities to make credits available.

1.22) What are the costs (in national currency) in actual practice for the renewal and maintenance of bridges during the last five years, and how have these differed from the corresponding estimates ?

The answers to this question should reveal whether during the execution of the maintenance work the payments actually made correspond to the requirements stated in the estimates, whether more funds are allocated as actually required, or whether the amounts made available in the budget are insufficient to complete the envisaged projects.

Seven administrations have given detailed answers. As already stated above, it is common practice to base the annual estimates on empiric values and individual estimates. From a comparison of the estimated and actually spent cost — assessed as an average for the last five years — it may be seen that the scheduled annual performance is frequently not attained which is probably due to an inadequate allocation of funds.

Only with regard to 50 % of the administrations the estimates nearly equal the allocations; in all other cases the actual expenditures for maintenance and renewals are behind the requirements. The situation is particularly unfavourable with regard to Germany and Austria. The arrears stated and expressed in percentages are for instance as follows :

Irish Railways	31.5 %
Nigerian Railway	29.16 %
Japanese National Railways .	23.0 %
Norwegian State Railways . .	17.95 %
British Transport Commission	7.2 %

TABLE 2. — I. Assessing of the carrying capacity of old bridges

1	2	3	4	5	6
ADMINISTRATION	by calculating the permissible percentage of the typical train load	without consideration of fatigue	with consideration of fatigue	on account of the particular permissible stresses for old bridges	on account of the normal permissible stresses for new bridges
1. *Association of American Railroads*	yes of Cooper E 72 e.g.E36 = 0.5 E72	without	—	yes = < 80 per cent of the yield point	no
2. *British Transport Commission*	no	without (estimated)	—	yes empiric value	no
3. *London Transport Railways* .	no	without	—	yes higher or lower in accordance with the actual condition	no
4. *Coras Iompair Eireann* . . .	no	without	—	yes following tensile tests	no
5. *Norwegian State Railways* . .	no	without	—	no	yes
6. *Swedish State Railways* . . .	yes	without	—	yes	no
7. *Grängesberg-Oxelösunds Järnvägar*	yes	without	—	yes following tensile tests	no
8. *Nigerian Railway Corporation*	no	without	—	yes prior to 1937 = 0.89 % of stresses for new bridges	no
9. *East African Railways* . . .	yes	without	—	yes prior to 1895 in accordance with BSS 15 (1948) otherwise as wrought iron	yes for steel manufacture subsequent to 1894

II. Admission of actual train loads

7	8	9	10	11	12	13
a) either accordance th a central assessing of their ercentages ith regard the effects of eir standard loadings	under the condition that the value indicated in column 7 is smaller than the value of column 2	*b*) or by measuring the stresses for each individual actual train load: no	yes	eventually by admitting *a*) limited exceedings with regard to the permissible load; *b*) speed restrictions	by special investigation for structural elements showing fatigue damages	manuals concerned and remarks
yes Cooper E 72 for motives only	yes	no	—	no	yes	AREA
—	—	—	yes	—	influence estimated	—
yes with alculation he equivalent uniformly distributed load locomotives and trains	—	yes with calculation of the equivalent uniformly distributed load of locomotives and trains		eventually speed restrictions		with consideration of the coefficient of oscillation
—	—	—	—	—	—	—
—	—	—	yes	—	—	—
yes	yes	—	—	—	—	—
—	—	only in separate cases for locomotives		—	—	—
—	—	—	—	—	—	—
—	—	—	—	—	—	BSS 153 medium gauge

TABLE 2. — **I. Assessing of the carrying capacity of old bridges** *(continued)*

1	2	3	4	5	6
ADMINISTRATION	by calculating the permissible percentage of the typical train load	without consideration of fatigue	with consideration of fatigue	on account of the particular permissible stresses for old bridges	on account of the normal permissible stresses for new bridges
10. *Rhodesia Railways*	no	without	—	yes 80 per cent of the permissible stresses for new bridges	no
11. *South African Railways* . .	yes with reference to the types of locomotives (column 9)	without	—	no	yes
12. *Japanese National Railways*	yes for remaining cross section less the age-corroded cross-sectional area with equivalent load A	without	—	yes particularly calculated as a function of the age multiplied with factor 1.153	no
13. *Malayan Railways*	no	without	—	yes wrought iron	yes other steels
14. *Deutsche Bundesbahn* . . .	yes of S (1950)	—	with	no	yes
15 *Indian Government Railways*	yes	without	—	yes for bridges erected prior to 1895	yes for steel manufactured subs. to 189

II. Admission of actual train loads *(continued)*

7	8	9	10	11	12	13
a) either in accordance with a central assessing of their percentages with regard to the effects of their standard loadings	under the condition that the value indicated in column 7 is smaller than the value of column 2	*b*) or by measuring the stresses for each individual actual train load: no	yes	eventually by admitting *a*) limited exceedings with regard to the permissible load *b*) speed restrictions	by special investigation for structural elements showing fatigue damages	manuals concerned and remarks
—	—	—	yes	—	—	—
yes as calculation of the equivalent uniformly distributed load of locomotives and trains	—	for locomotives by calculating the equivalent uniformly distributed load		special investigation for existing types of locomotives	—	—
yes with equivalent load B	yes	no	—	yes	—	—
—	—	—	yes	—	—	—
yes for all actual train loads	yes	no	—	yes *a*) 1.05 times for wrought iron 1.1 times for others (*) *b*) yes	—	BE 1951/55 (*) under the responsibility of the chief bridge engineer
—	—	—	—	yes on account of tests made with test specimen	—	Indian Manual para 12

TABLE 3. — **Permissible str**

1	2	3	4	5	6	7	8
ADMINISTRATION	*wrought iron* tensil stresses (+) year of manufacture			*wrought iron* compression stresses (—) year of manufacture			t
	old	old	new	old	old	new	old
1. *Association of American Railroads (AREA)*	1 125	—	—	1 125	—	—	1 1
2. *British Transport Commission (BSS 153)*	1 325	—	—	1 325	—	—	1 8
3. *London-Transport Railways :*							
condition good	1 325	—	—	1 325	—	—	1 8
condition bad	1 100	—	—	1 100	—	—	1 5
4. *Coras Iompair Eireann*	as a function of the yield point						
5. *Norwegian State Railways*	—	—	—	—	—	—	—
6. *Swedish State Railways*	—	—	—	—	—	—	1 1
7. *Grängesberg-Oxelösunde järnvägar TGOJ*	in accordance with material tests				—	—	800/ 1
8. *Nigerian Railway Corporation* (see *British Transport Commission*)	for structures prior to 1937 = 89 per cent of the permis						
9. *East African Railways*	945 (will be removed)			945 (will be removed)			94
	Steel subs. to 1895 : BSS 153			Steel prior to			1895
10. *Rhodesia Railways*	790	—	1 180	790	—	1 180	1 1
11. *South African Railways*	1 100	—	1 100	1 100	—	1 100	1 4
12. *Japanese National Railways*	prior to		effective	prior to		subs. to	prio
steel SS 41	1901	1901/50	1950	1901	1901/50	1951	190
σ_B = 41/50 kg/mm² λK							
0	1 125	1 350	1 500	1 247	1 315	1 385	1 1
30	—	—	—	1 200	1 265	1 332	—
60	—	—	—	1 060	1 117	1 176	—
90	—	—	—	827	871	917	—
110	—	—	—	618	652	686	—
13. *Malayan Railways BSS 153*	945	—	—	945	—	—	—
14. *Indian Government Railways :*							
normal stresses	915	—	915	945	—	945	—
with consideration of the ancillary stresses	—	—	—	—	—	—	—
15. *Deutsche Bundesbahn :*							prio 189
Load Case I λK	**1 600**	—	—	1 400	—	—	—
0	(1 680)	—	—	(1 470)	—	—	(1 6
30	—	—	—	(1 395)	—	—	—
60	—	—	—	(1 132)	—	—	—
90	—	—	—	(860)	—	—	—
110	—	—	—	(696)	—	—	—
Load Case II	**1 800**	—	—	**1 600**	—	—	**1 8**
	(1 890)	—	—	(1 680)	—	—	(1 8

old and new bridges in kg/cm²

components									connecting means			
9	10	11	12	13	14	15	16	17	18	19	20	21
mild steel						*shear τ*			*rivets*			
esses (+) manufacture		compression stresses (—) year of manufacture			wrought iron	ingot iron	mild steel	fatigue	shearing wrought iron	τ ingot iron	bearing wrought iron	stress σ ingot iron
old	new	old	old	new	old	old	new	$\varkappa = -1$				
—	1 125	1 125	—	1 125	—	—	—	1 125	—	—	—	—
—	1 890	1 890	—	1 890	1 040	1 415	865	—	—	—	—	—
—	—	1 890	—	—	1 040	1 415	—	—	—	—	—	—
—	—	1 575	—	—	865	1 180	—	—	—	—	—	—
(1 150)	—	—	—	(1 150)	—	—	—	—	—	—	—	—
—	—	1 100	—	—	—	—	—	—	—	—	—	—
—	—	800/ 1 000	—	—	—	—	—	—	—	—	—	—
esses												
cordance with material tests												
—	1 415	1 180	—	1 415	—	—	—	—	—	—	—	—
—	1 415	1 415	—	1 415	—	—	—	—	—	—	—	—
1901/50	subs. to 1951	prior to 1901	1901/50	subs. to 1951			Fn = 1 000			W= 1 000*		W= 2 200*
1 350	1 300	1 247	1 315	1 200	—	—	Fo = 800	1 050	—	B = 800	—	B = 1 800
—	—	1 200	1 265	1 155	—	—	—	—	—	—	—	—
—	—	1 060	1 117	1 020	—						* Remark :	
—	—	827	871	795	—						W = workshop	
—	—	618	652	595	—						B = site	
—	1 415	—	—	1 415	630	865	865	—	755	1 025	1 600	2 360
—	1 655	—	—	1 655	—	—	—	—	—	—	—	—
subs. to 1895	St 37	prior to 1895	subs. to 1895				St 37					
(1 760)	1 600	(1 470)	(1 540)	1 400	—	—	920	±1050	1 400	1 400	2 800	2 800
—	—	(1 395)	(1 424)	1 294	—	—	—	—	—	—	—	—
—	—	(1 132)	(1 186)	1 078	—	—	—	—	—	—	—	—
—	—	(860)	(901)	819	—	—	—	—	—	—	—	—
—	—	(696)	(730)	663	—	—	—	—	—	—	—	—
1 800	1 800	1 600	1 600	1 600	—	—	1 040	—	—	1 600	—	3 200
(1 980)	—	(1 680)	(1 760)	—	—	—	—	—	—	—	—	—

2) Metal bridges and viaducts.

2.11) When checking the stability of old bridges do you express their resistance as a percentage of the typical train on which the calculations for new designs of bridges are based, or do you use the actual train loads?

Do you take the effects of fatigue into account in the case considered?

What fatigue and permanent stresses do you consider admissible for the iron and steel used formerly and at the present time?

2.12) Do you check old bridges using the same limits of stresses as for new bridges, or have you adopted other limits?

In the latter case, how do you decide these limits, for example according to the elastic limit, and if so, to what extent?

See also question 2.23 below.

The evaluation of 15 answers shows that all administrations unanimously agree that the checking, new calculation, or measuring of the carrying capacity of old bridges is indispensible to admit, following the re-assessing, actual train loads.

Seven administrations (B.T.C., L.T.R., C.I. (Eire), Nor. R., Nig. R., Rhod. R, Mal. R.,) calculate their bridges for each actual train load concerned.

Eight administrations (A.A.R., Swed. R., T.G.O.J., EAfr. R., SAfr. R., Jap. R., Ind. R., D.B.) determine the carrying capacity of each member of an old bridge, i.e. as a percentage of their typical standard train load for new bridges.

The D.B. considers, in connection with this re-assessing, the fatigue limit.

Table 2 represents a synopsis of the methods used:

I) to re-assess the carrying capacity of old bridges;

II) for the admittance of actual train loads.

Table 3 indicates the permissible stresses (tensile, compressive, and shearing stresses) for different steels and connections used at old and new bridges.

2.21) Have you carried out *systematic tests* on the metal components used in bridges, in order to judge how they are ageing, taking into account modifications in their strength?

None of the administrations concerned undertook *systematic* tests on metal components with a view to be able to judge, on account of the *changings* which occurred, how the structure is ageing, taking into account alterations in the elastic characteristics of the material used. The L.T.R. carried out tests on the metal of a wrought iron girder bridge removed after 63 years' life which gave no indication that the wrought iron had become inferior.

2.22) Have you made *systematic tests* on metal bridges themselves in order to judge how the structure is ageing, taking into account modifications in the elastic characteristics of the materials.

Systematic tests in the strict sense of the question were not conducted.

The tests made in the U.S.A., Rhodesia, Japan, Malaya, India, and Germany are generally confined to ascertain the characteristics existing in the material used. The D.B. compares the measured values, as far as this is possible, with the data contained in the old delivery certificates, but considerable deteriorations of the elastic characteristics could *not* be found.

2.23) If you have not carried out any such systematic tests, have you made any technological tests on the components of metal bridges of a certain age in order to ascertain how they are ageing in relation to the characteristics such materials may be resumed to have had when the bridge was erected?

Of the 16 administrations questioned 7 mentioned technological tests which were carried out on components of old bridges. It is, however, agreed that alterations in the characteristics (ascertained during the tests) in comparison with the *probable* characteristics in the material at the time of delivery could be determined only when and where the components were subjected, without any doubt, to cold working (Japan, D.B., and Ö.B.B.).

2.3) What methods do you use to examine metal bridges, including ultra-sonic tests, magnetization, X-rays, dynamic stresses (tests with pulsator machines for example) ?

See table 4. Three administrations (A.A.R., South African Rlys., and Japanese Nat. Rlys.) reported on the experiences made as follows :

« Where there is any question regarding the carrying capacity of older bridges, electrical strain gauges are used to determine the actual strains in the various members under operating conditions. A mechanical oscillator has been used to test a bridge, but this is considered a very unsatisfactory method as it does not take into account other effects to which the bridge is subjected (A.A.R.). »

« Baldwin S.R. 4 strain gauges have been used to some extent to determine live-load stresses. Being of an electrical type and thus not subject to vibration effects, the results are consistent and accurate and have not shown serious differences from calculated values and no changes in the characteristics of the metal could be detected by this means.

Extensometer types used in the past have not been entirely satisfactory owing to vibration effects on moving parts.

A machine to drive an out-of-balance fly wheel has been devised and used to determine the natural frequencies of vibration of bridges. Comparison with calculated frequencies has revealed no case of serious discrepancy which might be ascribed to a marked change in the characteristics of the metal (South African Rlys.). »

« The sulphur-print test is conducted to find out the sulphur band in steel plate (Japanese Nat. Railways). »

2.4) What are the different types of deterioration which you have found together with the approximate frequency with which these occur ? Is the deterioration possibly due to :

2.41) fatigue of the materials;

2.42) defects in the materials;

2.43) defects in the design;

2.44) defects in the construction;

2.45) corrosion;

2.46) lack of maintenance;

2.47) other causes than those listed above ?

The Swedish State Railways, and the T.G.O.J. left this question unanswered since, as the Swedish State Railways indicate, damages of the above mentioned kind did fortunately not occur, or, if so, only to a minor extent. Most of the other administrations report *damages due to corrosion* as the most frequent cause, with the exception of the East African Rlys., the Nigerian Rly., the South African Rlys., and the Rhodesia Rlys. all stressing the importance of the climate conditions prevailing in their areas which are so that there is practically no corrosion in regions with continental climate conditions while steel bridges located in coastal regions are subject to heavy corrosion. Several administrations point out that the formation of rust is substantially favoured by the blast from steam locomotives, ashes dropping from locomotives, and by some liquid goods (cooling brine of refrigerator cars).

TABLE 4.

Method used	*AAR.*	*BTC.*	*LTR.*	*C.I. Eire*	*Nor. Rlys.*	*Swed. Rlys.*	*TGOJ.*	*Nig. Rlys.*	*EAfr. Rlys.*	*Rhod. Rlys.*	*SAfr. Rlys.*	*Jap. Rlys.*	*Mal. Rlys.*	*Ind. Rlys.*	*D.B.*	*Ö.B.B.*
1. Visual examination . . .	yes	—	—	—	—	—	—	yes	—	—	—	—	—	—	yes	yes
2. Mechanical examination (light hammer)	yes	—	—	—	—	—	—	yes	—	—	—	—	—	—	yes	yes
3. Deflection measurements	—	yes	—	—	yes	—	—	—	—	—	—	yes	—	—	yes	yes
4. Stress measurements. . .	yes	yes	—	yes	yes	—	—	—	yes	—	yes	yes	—	yes	yes	yes
5. Vibration measurements	—	yes	—	—	yes	—	—	—	—	—	—	yes	—	—	yes	yes
6. Vibration measurements with the aid of pulsators and vibrators	—	—	—	—	—	—	—	—	—	—	yes	yes	—	—	yes	—
7. Ultra-sonic tests	—	yes	—	—	—	yes	—	—	—	—	—	yes	—	—	—	—
8. Magnaflux inspection . .	yes	—	—	—	—	yes	—	—	—	yes	—	yes	—	—	yes	yes
9. X-rays	—	—	—	—	yes	yes	yes	—	—	—	—	yes	—	—	yes	yes
10. Chemical analysis . . .	—	—	—	—	—	—	—	—	—	—	—	yes	—	—	yes	—
11. Sulphur impression test .	—	—	—	—	—	—	—	—	—	—	—	yes	—	—	—	—
12. Microscopic examination	—	—	—	—	—	—	—	—	—	—	—	yes	—	—	yes	—

It must be assumed that several administrations have not indicated all methods used by them.

Parts particularly subjected to corrosion are :

a) all parts difficult to be maintained or insufficiently ventilated;

b) all parts subject to the aforementioned chemical influences.

Inadequate maintenance is not mentioned as a special and direct cause, but only as a factor contributing to the formation of rust.

Fatigue failures are also a kind of damage frequently encountered, e.g. fatigue cracks at components belonging to the floor construction (U.S.A., Great Britain (L.T.R.), South Africa, Japan, and Austria). The A.A.R. mentions also some fatigue failures which occurred in chord members. Loose rivets are also frequently quoted; it is not explained whether these rivets were loose right from the beginning or whether they worked loose due to loading.

Defects in the design and the construction are mentioned (A.A.R., Nigerian Rlys., East African Rlys., Japanese Rlys., D.B., and Ö.B.B.), in particular with regard to structures erected 40 to 50 years ago. Defects in material are reported by all administrations at the last place. Other causes than those mentioned above are :

derailments and misplaced loads (U.S.A.);
yielding of the abutments (Ö.B.B.).

2.5) What are the structural components principally affected by the deterioration due to the causes listed under 2.4) above :

2.51) main beams with full web, composite or laminated;

2.52) main trellis girders, straight or arched;

2.53) wind bracing and cross beams;

2.54) longitudinals and cross pieces, as well as their assemblies;

2.55) sheets and plates used for the decking;

2.56) arrangements for collecting and draining off water ?

The following components are principally affected by corrosion :

1) All parts difficult to access, easily polluted, insufficiently ventilated, i.e. all frequently wet components located near the bearings on the end abutments, as the lower booms of the main girders, and cross beams, bracing bars, gusset plates, connecting angles, rivet or screw heads;

2) The flanges of longitudinals (sleeper bearers) where the wooden sleepers are supported;

3) The upper surfaces of all structural parts where dirt, ashes, goods, and moisture may become aggressive;

4) Floor and main girder constructions bridging tracks used by steam locomotives; in this connection it should be mentioned that the working of locomotives on the ascending track has a much more detrimental effect than on the descending track;

5) The surfaces of fine-meshed bracing constructions being in contact with each other which show gaps due to drift rust so that they cannot be properly cleaned and maintained;

6) Drain pipes and buckle plates of closed deck structures;

7) Structural parts forming water traps, as e.g. U-shaped bottom flanges — even if they are provided with holes serving drainage purposes.

The occurrence of fatigue cracks is chiefly confined to : crossbeams and longitudinal girders of bridge floor constructions, in particular if they are improperly cut; further to : bracing bars and coverings. Rivets — worked loose — could be found in all structural parts.

The design and construction failures mentioned by several administrations (Nigerian Rly., South African Rlys., and Japanese Nat. Rlys.) are attributable to obsolete construction methods, hastily erected structures, poor standard of labour, and to insufficient skilled supervision at the time the bridges were constructed (Nigerian Rly.).

2.6) What steps are taken when there is serious deterioration affecting the strength of the bridge, whilst awaiting definitive overhaul? Examples: reducing the speed of the trains, reduction in the loads allowed, temporary repairs, introduction of temporary components or supports.

Regardless of the extent of the damage, all administrations resort to speed restrictions.

In Japan these speed restrictions are imposed only following a special investigation carried out by experts of central offices. Diagrams and formulae were established to determine the speed restriction to be imposed (see appendix 1).

Reduction in the load — including the changing of the train composition — is indicated by eight administrations (B.T.C., Irish Rlys., Swedish State Rlys., Nigerian Rlys., East African Rlys., Japanese Nat. Rlys., Malayan Rly., D.B., and Ö.B.B.) as a possible measure; the East African Rlys. regard this reduction in loading as the last resort.

The South African Rlys. explicitly report that this measure is *not* practised to any extent. They prefer in such instances to divert the traffic to alternative routes while temporary deviations are built.

The strengthening of dangerously deteriorated bridges, before a reconstruction can commence, by temporary supports is practised by nearly all administrations. The possibility to replace damaged bridges by temporary structures is indicated by five administrations (L.T.R., B.T.C., Irish Rlys., D.B., and Ö.B.B.).

Minor damages are generally at once temporarily repaired.

2.711) What methods are used to protect metal bridges against corrosion? Painting, metalization, chemical processes, composition of the metal (for example addition of copper).

Painting is indicated by all administrations as the most common means to protect a structure against the formation of corrosion. Tests with structural copper-alloy steels were carried out in the United States and in Austria (in one case only). The A.A.R. reports in this connection as follows: « Some of the new metal bridges in this country are fabricated from copper bearing steel to offer some protection against atmospheric corrosion and then painted for additional protection. »

Six administrations use metalization (at present by the spraying method); these administrations are: A.A.R. (to protect the top flanges of the longitudinal floor girders), B.T.C., L.T.R., South African Rlys., Indian Rlys., and D.B. The A.A.R. and the Indian Rlys. stress that this method is very expensive thus preventing its extensive use. A.A.R., B.T.C., L.T.R., and D.B. have answered that they limit the metalization to certain particularly strained surfaces of structures or to individual components, as buckle plates and gutters. The D.B. formerly used to lead-coat their buckle plates in a railway-owned workshop.

2.712) When designing metal bridges, is it the practice to increase the calculated sections in steel in order to allow for future losses through corrosion? If so, for what components, and to what extent?

Five administrations answered this question in the negative. Nearly all of the remaining 11 administrations replied « generally not », but they quote individual cases where such allowances for future losses through corrosion are duly considered. The components in question

are those where the loss of section, instead of unit stresses, it the controlling factor, as e.g. parts which are difficult to clean and paint, components which are partly erected in the water or the earth and partly projecting into the air, components which are subjected to influences causing their deterioration and which, due to their pollution with aggressive substances, easily corrode.

The additions required are in the magnitude of 1.6 mm or a minimum thickness of 8, 9.5, and 10 mm for plates.

The Japanese Nat. Rlys. are using for the flange plates of their plate girders cross-sections which exceed the normal

TABLE 5.

	Priming coat			Finishing coat			Total
	Red lead	Linseed oil	Lead cyanamide	Alumin. paint	White lead	Bitumen tar solut.	
A.A.R.	2	1	—	1	—	—	4
*L.T.R.**	1	—	—	—	1	—	4
Irl. E.	2	—	—	1	or	1	3
Nor. R.	2	—	—	—	2	—	4
Swed. R.	2	—	—	—	2	—	4
T.G.O.J.	2	or	2	—	2	—	4
Nig. R.	1	—	—	2	—	—	3
EAfr. R.	1**	—	—	2	—	—	3
Rhod. R.	1	—	—	2	—	—	3
SAfr. R.	1	—	—	—	2	—	3
Jap. R.	1	or	2 ***	1 × iron oxide paint brown or green		— —	3
Mal. R.	1	—	—	—	—	2 warm	3
Ind. R.	1	1	—	—	2	—	4
D.B.	2	or	2	2 (with iron mica)		—	4
Ö.B.B.	2 ****	—	—	— (also with iron mica)	2	—	4

* 2 intermediate coats with silica-graphite.
** with chromium oxide yellow.
*** or zinc oxide.
**** on a linseed oil or plastic basis.

dimensions by 33 1/3 %. The D.B. and Ö.B.B. protect their sleeper bearers (in case the sleepers are directly posed) by means of rust protecting plates having a thickness of 8 to 10 mm.

2.721) Please state what anti-rust paints you use for old and new bridges, and indicate the number of coats used, as well as the method of application.

50 % of the administrations require 4 coats while the remaining railways are content, under normal conditions, with 3 coats.

2.722) What regulations are in force as regards the preparation of the surfaces to be protected by painting in old and new bridges? Are these regulations satisfactory?

The following regulations or recommendations of the undermentioned 10 administrations are specifying how old and new bridges are to be painted:

A.A.R. Recommendations of the « Steel Structure Painting Council »;

B.T.C. Civil Engineering Handbook No. 10;

Ind. R. Department Circular P 300 of the Chief Engineer;

Swed. R. Handbook on rust protecting coats for steel structures subjected to atmospheric influences;

T.G.O.I. Regulations of the Swedish Committee for Corrosion and « Steel Bridge Norms »;

Nig. R. Corresponding regulations of the civil engineering department;

Jap. R. I.N.R. technical specifications for deliveries of paints, paragraph 18;

Mal. R. Regulations are mentioned but not quoted in detail;

D.B. DV 807 (Rost) « Technical Specifications for rust protection of steel structures »;

Ö.B.B. Handbook 720 « Execution of Works »;
Handbook 721 « Composition of Materials »;
(both handbooks must be revised).

With the exception of one railway (Ö.B.B.) all administrations agree that their regulations are sufficient. Comments made by all administrations reveal that the procedure applied for the cleaning and removal of old and weathered paint and rust is nearly uniform in all cases. Only the Japanese Nat. Railways mention that it is not allowed to remove old paint with the aid of chemicals.

2.723) Is any special painting done in the case of bridges in special positions?

Nine administrations answered in the negative; seven administrations report that special paintings are done. The following examples were given:

a) Bitumastic primer and a final coat of bitumastic paint for structural parts which are exposed to heavy blast from locomotives or to ashes dropping down from locomotives (L.T.R., D.B., Ö.B.B.);

b) Paints with a caoutchouc chloride or plastic basis for parts which are exposed to sea or fresh waters and to blast (Swed. R., D.B., Jap. R.);

c) A special treatment is described by the Japanese Nat. Rlys. for parts of a movable bridge (at a ferry terminal) which are submerged in water:

1. washing with acid;
2. washing primer;
3. three anti-rust cold plastic coats;
4. three cold plastic coats.

In spite of all these measures a service life of only four years is attained.

d) In Sweden the following procedure is applied for installations similar to those mentioned under *c*):

two coats of red lead (caoutchouc chloride basis) one final coat with

anti-condensation paint (2 mm thick);

c) In the United States the following methods are applied in special instances:

the steel is given a wash primer and is then primed with a venyl red lead type of paint. Subsequently it receives two finishing coats of aluminium paint also to protect the steel against aggressive liquids (brine from refrigerator cars).

2.724) What precautions are taken to protect surfaces permanently in contact?

Surfaces being in permanent contact are distinguished as follows:

a) types of steel;

b) types of connecting means (rivets, high-grade steel-screws, and welding).

For riveted structures made from St 37 or similar steels, a red lead coat of both surfaces being in contact is generally considered as sufficient. The D.B. prescribes coats with zinc oxide or iron oxide based on linseed oil or phtalic resin; an intermediate coat is not applied in connection with such structural parts subjected to heavy repetitions of dynamic stresses.

The Austrian Federal Railways do not require the painting of the contact surfaces of steel as far as riveted structures made from St 50 are involved, while the Japanese Nat. Rlys. prescribe the cleaning of these surfaces with boiled oil.

The coating of welded connections is dispensed with in some instances (Jap. R., D.B., Ö.B.B.), provided that there will be no danger of corrosion on account of the very compact welding seams.

In case high-grade steel screws are used as connecting means (A.A.R. and D.B.) it is advisable not to coat the contact surfaces in consideration of the coefficient of friction which should be as high as possible.

2.725) What is the average period on your railway between two paintings? Do you make any distinction between touch up or partial painting and a complete repainting?
See Table 6.

2.726) Have you observed any marked differences in the way the paintwork stands up on different bridges close to each other? If so, have you found it possible to decide for what reasons?

50 % of the administrations report that they have observed marked differences with regard to the behavior of the paints.

These differences are caused by:

a) sea winds (seaward side);

b) heavy rain falls (weather-side);

c) sun rays (*);

d) blast of locomotives and industrial plants;

e) chemicals;

f) permanent humidity.

2.727) Have you encountered any special difficulties in assuring the proper conservation of the paintwork of watertight decking? If so, do you think special constructional arrangements could prevent or retard the damage?

With the exception of 5 administrations (Nor. R., Swed. R., T.G.O.I., Nig. R., and EAfr. R.) where such bridges are not existing, all other administrations report on considerable trouble encountered in assuring proper conservation of the paintwork of watertight decking (both sides, top and bottom) due to the fact that the drain pipes and buckle plates corroded at their lowest points and at the rivet connections of the deck girders.

The renewal of bitumastic interior coat-

(*) The sun has a favourable influence insofar as it affects a rapid drying of the structure, on the other side the sun rays destroy the paint.

TABLE 6.

	Periods between two subsequent paintings			
	Coastal areas or unfavourable locations	Industrial regions with a moist climate	favourable locations	Patch painting used or not
A.A.R.	2 — 3 *	several	several	no
B.T.C.	3	5	7	yes
L.T.R.	—	4	15	yes
C.I. (Eire)	in the average 7			yes
Nor. R.	10	—	20	no
Swed. R.	5 — 8	15	20	yes
T.G.O.I.	in the average 10			yes
Nig. R.	3	—	5	no
EAfr. R.	5	—	10	yes
Rhod. R.	5	—	20	yes
SAfr. R.	?	?	?	no
Jap. R.	in the average 8			yes
Mal. R.	in the average 10			yes
Ind. R.	4	—	10	hardly
D.B.	12	15	25	seldom
Ö.B.B.	—	—	30	yes

* When the steel is subjected to aggressive chemicals.

ings of the decks (ballast bed) is always expensive and hampers the operating of trains. The subsequent filling up of the troughs with concrete (South African Railways) or using asphalt planks (A.A.R.) is not always suitable since the drainage of the water is rendered more difficult.

The D.B. and Ö.B.B. avoid — as far as this is possible — to provide new constructions with buckle plates but they select watertight deckings making use of flat plates provided with sloping surfaces in the longitudinal and transverse directions so that the water is diverted behind

the abutments. The surfaces in contact with the ballast receive three primers (coal-tar pitch solution). The Ö.B.B. are of the opinion that a protection of this paint work is necessary by means of concrete or tiles. The D.B. avoids a direct contact between deck plates and ballast stones showing sharp edges by placing a layer of well-rounded pebbles.

2.728) In a more general way, do you think you can suggest any variation in the usual constructional arrangements which would encourage the proper conservation of the paintwork ?

Six administrations (B.T.C., L.T.R., C.I. (Eire), Nor. R., D.B., and O.B.B.) stress the importance of smooth and simple surfaces of *welded* structures.

The Irish Republic Rlys. mention that special attention should be given to adequate drainage arrangements.

The South African Rlys., the D.B., and the Ö.B.B. recommend a careful selection of suitable steel sections or cross section designs to avoid gaps and water traps (rolled sections and box girders). The D.B. obtained very satisfactory results with closed box steel sections which showed no inner corrosion when hermetically sealed.

2.729) Are bridges repainted at non-predetermined intervals, based solely on the state of repair of the bridge, or is it carried out according to a definite cycle established once for all ?

Only five administrations report that they are conducting re-painting within predetermined intervals (Irish Republ. Rlys., Nig. R., EAfr. R., Mal. R., and Ind. R.). Nearly all remaining administrations (11) report that the question whether a re-painting of a steel bridge has to be made or not depends on the result of the inspection of the old paint, e.i. the bridges are painted as required.

The Japanese Nat. Railways have developed a so-called paint coat tester to examine old paints which permits to ascertain and to measure microscopic small damages with the aid of an electrolytic solution (ammonium chloride) a zinc plate, and a micro-ammeter.

2.731) Have you used metalization ? If so, what method have you chosen amongst those known ? What results have you obtained ? Do you apply one or more coats of paint after metalization ?

Apart from individual parts as buckle plates, drains, bar grates on footways etc. metalizing has been actually used by three administrations only (A.A.R., B.T.C., and SAfr. R. in one case for test purposes).

In the United States and in South Africa zinc or aluminium were applied by the spraying method. Surfaces treated in such a manner were only painted in some cases. The South African Railways consider zinc spraying satisfactory but the paint does not adhere well to a zinc surface.

The B.T.C. mentions a wire process as opposed to powder. A coat of zinc chromate paint applied followed by two coats of approved paint. Insufficient time has elapsed since this has been done to enable a judgement on the performance. It must be assumed that the above quoted method is a painting procedure and not a metalization process proper.

2.732) What arrangements have you adopted as regards the preparation of the surfaces to be protected ?

Seven administrations have given a detailed answer to this question. However, it is obvious that the removal of rust is manually performed by nearly all administrations i.e. with the aid of scaling hammers, spatulas, scrapers, and wire brushes. In difficult cases by means of sand blasting. Other measures applied are as follows :

a) application of cleaning solvents and steam cleaning (A.A.R., L.T.R., Swed. R., D.B.) :

b) use of power brushes and power hammers (A.A.R., L.T.R., C.I. (Eire), Swed. R., SAfr. R., Jap. R.);

c) flame cleaning (L.T.R., Rhodesia R., D.B., Ö.B.B.);

d) chemical rust removal (rust conversion); however, only for small parts by the dipping process (D.B.).

The Swedish State Railways and the German Federal Railways require explicitly the removal of the roll or mill scale. Other administrations point out that the surfaces to be painted must be completely dry and that they must eventually be heated prior to their painting.

2.74) Have you used or considered using other methods of protection? If so, please give a detailed description and state the results obtained.

Some of the methods mentioned under this question as:

bitumen solutions (B.T.C.);

fixing of additional covering and blast protection shields (Japanese Nat. Rlys.) and

protection of endangered plate girders by concrete or the installation of composite girders (Jap. R.);

are generally well-known — also as far as the results obtained are concerned; the installation of cover plates preventing a direct contact between carrying members and the ballast, etc. is also frequently practised.

Tests with the zinc powder spraying or painting methods (B.T.C., D.B.) may be considered as new-developed processes; it should be mentioned that, in this case, zinc powder is used as cathode protection applied on a linseed oil or synthetic resin base where the powder is mixed with the paint prior to its application or where it is sprayed on the already applied paint coat. A prerequisite is the thorough cleaning of the surface to be protected. 2 to 3 coats are applied. It is not yet possible to report on the results.

2.75) Have you been led to use, at least to some extent, rustless steel or other metals or alloys in order to avoid corrosion of the component parts of the structure?

This question has been answered by all administrations in the negative.

2.81) What methods do you use for the repair of metal bridges showing defects due to ageing? Have you any particularly interesting cases to report?

Four administrations (T.G.O.I., Nig. R., SAfr. R., Mal. R.) report that they have not observed any defects due to ageing worth mentioning.

Nine administrations (A.A.R., L.T.R., C.I. (Eire), Swed. R., EAfr. R., Jap. R., Ind. R., D.B. and Ö.B.B.) report that in such instances where structural parts are weakened by corrosion or cracks these parts:

are replaced (in case of minor damages) or they

are built up by connecting up new sections or plates (in case of heavy damages) which

are riveted, screwed, or welded to the damaged parts.

The A.A.R. indicates that loose I-bars were tightened by the heating and shrinkage method. The L.T.R. mention the case of a plate girder through bridge where the deck construction was of plates and troughs where the latter had arrived at the end of their useful life. The defective troughs were removed and replaced by built up members made up of 2 channels, with cross members between them to support the longitudinal timbers. As the main girders and cross girders of this bridge are in very good condition, the useful life of the bridge has probably been extended by another 40 years or more.

It may be presumed that loose rivets are replaced — at all administrations — by new ones — probably by such having a larger shaft diameter or by fitted bolts.

In Germany (D.B.) and Austria (Ö.B.B.) short cracks are arrested — as far as they do not decisively impede the carrying capacity — by boring a hole at the end of the crack.

2.82) What has been your experience as regards welding in repairing or strengthening steel bridges?

Eight administrations (L. T. R., C. I. (Eire), Nor. R., Swed. R., T.G.O.I., Nig. R., EAfr. R., SAfr. R.) report that welding to repair or strengthen bridges is not used or even rejected since it was found to be unsatisfactory.

The remaining eight administrations report that welding is used — to a more or less extent — for the repair and strengthening of structures. Frequent use is made in the United States, Rhodesia, Japan, and Germany (D. B.). These administrations indicate that the results are quite satisfactory.

Prerequisites to obtain satisfactory results are:

the condition that the old material must be suitable for welding and the careful execution of the welding.

Effective 1931 the Japanese National Rlys. have reinforced rolled sections and plate girders of 1 650 bridges by welding additional sections to them.

The German Federal Railways give one example of several welding jobs carried out. The method applied is similar to the above mentioned and refers to the welding of a damaged rigid frame with two hinged supports (see appendix 2).

2.83) Can you give any examples of particularly interesting recent strengthening work carried out in order to eliminate constructional defects?

Coras Iompair Eireann.

Serious defects developed near the expansion bearings of a steel deck-type underbridge constructed in 1924 consisting of ten 16 m plate girder spans supported on steel trestles. The defects were traced to weakness in the cross girders at the head of the trestles and inadequate arrangements. The defects were removed by constructing concrete piers to encase the steel trestles and provide new bearings to support the main girders.

South African Railways.

In some old spans the designed connections of cross girders to main girders were unsatisfactory since the rivets worked loose and the plates arranged at the lower chord cracked. These plates were replaced by angle sections.

Japanese National Railways.

The six mentioned cases refer to constructional defects (see appendix 3).

2.91) Have you had to strengthen any metal bridges in order to enable heavier loads than those originally calculated to be carried?

If so, please give a brief description of the work done and state what precautions were taken to ensure solidarity between the old and new components.

Nearly all administrations mention the strengthening of steel bridges:

1. Frame members, main-, cross-, and longitudinal girders were strengthened by riveting or welding additional material to them to increase the cross section. Connections are strengthened by using heavier strengthening means and by the installation of extension butt straps (rivets in double shear) or continuity butt straps (Swedish State Rlys., T.G.O.I., Nig. R., EAfr. R., Rhod. R., SAfr. R., Mal. R., Ind. R., D.B., Ö.B.B.). Where — as in many cases — the removal of the dead load was impossible these strengthening cross sections have been used to carry the part of live loads;
2. Main girders were supplemented by the installation of one or even two parallel

girders which are rigidly braced together to ensure equal deflection of the girders (Swed. R., SAfr. R.). Doubling the number of cross girders as well as their replacement by stronger members are common methods applied in South Africa;

3. Halving panel lengths of weak bridges by construction of centre piers (Swed. R., Nig. R., Rhod. R.);

4. Plain web girders and lattice girders (even those having a large span) have been frequently strengthened by increasing their height (Swed. R., Jap. R., D.B.). Appendix 4 shows an example of the German Federal Rlys.

Some reports of the Japanese National Rlys. on the strengthening of bridges are described in appendix 5.

2.92) Do you think it is advantageous in general to strengthen bridges in order to enable them to take heavier loads?

Please state what factors you take into account in estimating the advantages to be obtained from strengthening an old bridge which is still in good condition rather than replacing it by a new bridge.

Nearly all administrations quote that it is considered advantageous in general to strengthen steel bridges as long as the condition of the bridge is satisfactory and a sufficient service life may be expected from the reinforced bridge. Moreover, it is required to compare the cost requisite for a new structure with those accruing for a strengthening including *all* ancillary costs. In Japan the age limit is expected, in the case of strengthening, at half of that of a new bridge.

3) Bridges and viaducts in masonry and concrete.

3.1) What are the different kinds of damage which occur owing to the age of the bridges and approximately how often? The damage in question may be due to:

3.11) defects in the materials;

3.12) defects in the design;

3.13) poor execution of the work:

3.14) atmospheric conditions and ageing;

3.15) lack of maintenance;

3.16) settling of the ground;

3.17) causes other than those mentioned above.

With the exception of the Malayan Rlys. and the Nigerian Rlys. where there are no or only a very few such masonry and concrete bridges all other administrations have reported on damages and their causes. Only the German Federal Rlys. have given percentages on the frequency of the damage causes. However, from the answers it may be assumed that the frequency of reoccurrence is — with only a few exceptions due to climatical and geographical conditions — as follows:

a) formation of cracks;

b) breakage and spalling of the face;

c) washing out of mortar;

d) destruction of stones and concrete;

e) exposure of reinforcement steel.

The formation of cracks is predominantly traced to the following causes:

a) exceeding of the permissible earth pressures (inadequate foundation) (L.T.R., A.A.R., T.G.O.I., Rhod. R., SAfr. R., Jap. R., Ind. R., D.B.);

b) lacking expansion joints in particular between abutments and wings (A.A.R., L.T.R.);

c) inadequate ballast cover and unfavourable load distribution (L.T.R., EAfr. R., SAfr. R., Jap. R., Ind. R., D.B.);

d) lacking reinforcement steels in the transverse direction in case of bridges using encased rolled beams (EAfr. R., D.B.);

e) settling of the ground and subsidence (Jap. R., Rhod. R., A.A.R., D.B.).

The general view with reference to cracks has been explained — by the South African Rlys. — as follows : as long as cracks are not progressive and it is quite evident that stability is not affected, no steps are taken beyond keeping a close watch on such structures to see that no changes are occurring.

The breakage and spalling of masonry as well as the destruction of concrete, stones, and mortar is traced, in the first line, to defects in the design and, in the second line, to defects in the material and to poor execution of the work :

a) lacking or inadequate waterproofing of masonry and concrete structures to avoid the unfavourable influences of the water which, to a more or less extent, is mixed with aggressive chemicals or which during freezing has an explosive effect as well as improper draining are the causes most frequently cited (A.A.R., L.T.R., Nor. R., Swed. R., T.G.O.I., Rhod. R., Jap. R., D.B.);

b) seven administrations complain about the use of improper materials, i.e. natural stones and bricks being too weak and porous, and the employment of unsuitable aggregates for making concrete and mortar (A.A.R., L.T.R., T.G.O.I., Rhod. R., SAfr. R., Ind. R., D.B.);

c) far too high water contents (in the concrete) and poor compacting had, corresponding to present-day knowledge, a decisive influence on the condition of the concrete. Four administrations reported such failures due to the poor execution of the work (A.A.R., SAfr. R., Ind. R., D.B.).

The spalling of the concrete, which frequently occurred after quite some time, thus exposing the reinforcement steels, is traced to poor execution of the work. The cover of the reinforcement was insufficient so that the humidity of the air is allowed to penetrate thus coming in contact with the iron, and the formation of rust causes the spalling of the cover (L.T.R., Swed. R.). The German Federal Railways mention in this connection that the formation of rust at the reinforcement steels is favoured by chlorides contained in the cement and the aggregates.

Poor maintenance is of no great importance as damage cause. Properly constructed masonry and concrete bridges do not require extensive maintenance as compared with steel structures.

The cleaning of the mansonry, i.e. the removal of grass, moss, and bushes, the scratching out of the joints, and the filling up of these joints with new mortar is only required in greater time intervals and it is therefore comparatively inexpensive.

The timely renewal of the waterproofing and the cleaning of the interior draining facilities is of utmost importance. In spite of the fact that this work is only required 2 to 3 times during the service life of a bridge — depending in each case upon the quality of the construction material used — the costs involved are very high (A.A.R., D.B).

Other damages caused by exterior influences are mentioned by 2 administrations :

the Japanese National Railways quote destructions caused by floating logs and rolling rocks;

and the South African Railways mention the undermining of piers and abutments during a period with intensive rainfalls, frequently accompanied by cloud bursts.

3.2) What methods do you use when examining masonry and concrete bridges, including possibly non-destructive processes ?

Table 7 shows the different inspection methods used by the administrations. Many railways report that they rely

TABLE 7. — **Methods to examine masonry and concrete bridges.**

Inspection method	*A.A.R.*	*B.T.C.*	*L.T.R.*	*C.I. (Eire)*	*Nor. Rlys.*	*Swed. Rlys.*	*TGOI.*	*Nig. Rlys.*	*Rhod. Rlys.*	*EAfr. Rlys.*	*S.Afr. Rlys.*	*Jap. Rlys.*	*Mal. Rlys.*	*Ind. Rlys.*	*D.B.*	*O.B.B.*
1. Visual	yes	yes	yes	yes	yes	yes	yes	—	yes	yes	yes	yes	—	yes	yes	yes
2. Tapping with hammers .	—	—	—	—	—	—	—	—	—	—	yes	—	—	yes	yes	yes
3. With mechanical sledge hammers	—	—	—	—	—	yes	yes	—	—	—	—	—	—	—	yes	—
4. Test specimen of drilled cores	yes	—	—	—	—	yes	—	—	—	—	—	—	—	—	yes	yes
5. Measurements to ascertain any variation of the geometrical form	—	—	—	—	yes	—	—	—	—	—	—	yes	—	—	yes	—
6. Electric measurements of the depth of reinforcement, (ultrasonics, X-rays) . .	—	—	yes	—	—	—	yes	—	—	—	—	—	—	—	—	—
7. With techno-endoscope (possib. of photographs) .	—	—	—	—	—	—	—	—	—	—	—	—	—	—	yes	—
8. With sonometer (sonoscope)	yes	—	—	—	—	—	—	—	—	—	—	yes	—	—	—	—
9. With tensometer (Huggenb.)	—	—	—	—	yes	—	—	—	—	—	—	yes	—	—	—	—
10. Chemical examinations .	—	—	—	—	—	—	—	—	—	—	—	—	—	—	yes	yes

TABLE 8.

Result	Thickness	Type of material used	
Satisfactory	1/2"	Bituminous fabric with hessian base placed in position in hot bitumen.	*B.T.C.*
Satisfactory	3/4"	Asphalt, bitumenised dampcourse over joints.	*C.I. (Eire)*
Satisfactory	?	2 layers of tar paper. 3 coats of tar	*Nor. R.*
Satisfactory	? 15 mms.	Prior to 1945. 2 layers of tar paper. 3 coats of warm oil asphalt To-day : 1 coat of a cold asphalt solution. 1 thick layer of a special mastic asphalt.	*Swed. R.*
Satisfactory	? 20 mm	Formerly : several layers of asphalt felt with bitumen coats between the layers. To-day : one 20 mm thick mastic asphalt layer.	*T.G.O.I.*
Rather satisfactory	?	Several bitumen coats either poured on or applied by brush.	*SAfr. R.*
Satisfactory	?	A watertight layer consisting of 1 to 3 membranes.	*Jap. R.*
Satisfactory	8 mm 4 mm	Bitumen and coal-tar pitch (hot as solution or as emulsions). Jute, glass wool fabrics or metal foils are used as carriers for waterproofing mediums; thermoplastic materials which can be welded together.	*D.B.*
Satisfactory	20 - 50 mm	Primer with a bituminous solution or emulsion. 2 layers of 22 per cent mastic asphalt intermediate layer of paper or cardboard. 0.5 mm wire net. 1 layer of 16 per cent mastic asphalt or carriers for waterproofing mediums as described under column *D.B.* Only limited use of thermoplastic materials since they have to be imported.	*Ö.B.B.*

exclusively on a visual inspection and on tapping with hammers. Cracks ascertained are covered by cement or plaster pads to be inspected within shorter periods. In some cases use has been made of magnetic indicators and electric measuring devices to check the depth of reinforcement (L.T.R., T.G.O.I.).

If it is suspected that the interior of a solid body is destroyed several administrations use special devices which serve to obtain reliable results, i.e. from the exterior :

sledge hammer (Frank, Schmitt);

concrete pistol;

tensometer (Huggenberger);

sonoscope;

or from the interior :

core drills used to obtain an undestroyed core;

techno-endescope with the possibility to take photographs.

Measurements serving to ascertain any variation of the geometrical form of the structure are probably much more frequently used as stated in the answers of the administrations. Chemical examinations of mortar and concrete specimens are carried out by the German Federal Railways and the Austrian Federal Railways.

3.31) On masonry and concrete bridges, including those with concrete encased girders, what materials are used for the casing ? What results have been obtained ?

Different views have been expressed by the administrations regarding the necessity to make masonry and concrete bridges waterproof.

The Nigerian Rly., East African Rlys., Malayan Rly., Rhodesia Rlys., and Indian State Rlys. report that waterproofing is not usual (which is obviously due to the favourable climatic conditions prevailing in these countries). The preceding Table 8 indicates the material and methods used for this purpose by other administrations.

3.32) Please give details about the thickness, siting and arrangements adopted for the casing, in particular as regards their extension over the spandrels.

A reply to this question was only furnished by three administrations (Swed. R., T.G.O.I., and D.B.). In Sweden copper sheets are used as a medium to warrant the impermeability of the expansion joints, i.e. joints allowing for the separate movements of individual structural parts, while the kind of protection used in Germany depends on the size and the type of the movements to be expected. In case of minor movements it suffices to cover the joints by gluing a strap of the fabric cover which is used as a carrier for waterproofing mediums or by strengthening already existing fabrics, extending beyond the joints, by an additional strap. If major and slow movements are to be expected the fabric covering the expansion joint is strengthened by one or several copper straps. For major and rapid movements loops made from copper sheet or thermoplastic materials are used which can freely move in grooves which are arranged parallel to the joint. Moreover, the fabrics covering the grooves are additionally reinforced by copper sheets.

At structures which have not been provided with such a protection to safeguard the impermeability of the joints or which receive only a surface coating, the expansion joints are covered and made impermeable to water by plastic fabrics.

3.34) What do you consider is the average life of the casing of masonry and concrete bridges ?

The question of the service life of the waterproofing used in case of masonry and/or concrete bridges was answered as follows :

	Old waterproofing	Modern waterproofing
B.T.C.	—	more than 100 years
Swed. R. . .	15 to 20 years	(no exper.)
SAfr. R. . . .	20 years	—
Jap. R. . . .	50 years	—
D.B.	25 to 30 years	more than 100 years
Ö.B.B.	30 to 40 years	—

It may be generally assumed that a waterproofing being properly arranged and executed will attain a service life equaling that of the structure it is protecting,

i.e. under the condition that the medium used to obtain the waterproofing is protected against any mechanical damage and that damages to the structure (formation of cracks, settling) do not destroy the waterproofing (B.T.C., D.B.).

According to the view as expressed by the German Federal Rlys. it may be expected that a waterproofing made of synthetic thermoplastic materials or of metal foils will attain a considerably longer service life as one made of organic materials as the latter will rot quickly.

3.35) Are there any types of bridges on which you consider there is no point in providing a casing?

Several administrations are of opinion that the provision of a special waterproofing can be dispensed with in case of masonry and/or concrete bridges under the condition that:

a) the concrete is sufficiently compact (Swedish State Rlys., T.G.O.I., Jap. R.);

b) the concrete is prestressed transversely and longitudinally [C.I. (Eire), D.B.];

c) special measures are taken to assure the rapid draining of the water (sloped upper surfaces, adequate drainage ducts, and the fill must consist entirely of stone ballast of such size so as to drain easily);

d) the rails are directly placed on the concrete (without ballast) (Nor. R., D.B., Ö.B.B.).

The application of a protective coating — repelling water, oil, and aggressive chemicals — is recommended by all administrations.

3.41) What do you consider the minimum thickness under the sleepers of the layer of ballast on bridges in order to avoid damage to the casing due to the carrying out of work on the line and the local stresses due to trains passing over them?

	A.A.R.	*B.T.C.*	*L.T.R.*	*C.I. (Eire)*	*Nor. R.*	*Swed. R.*	*T.G.O.I.*	*Nig. R.*
cms . . .	15.25	15.25	10	10	21	20 to 40	30	—
inch . . .	6	6	4	4	—	—	—	—
	EAfr. R.	*Rhod. R.*	*SAfr.R.*	*Jap. R.*	*Mal. R.*	*Ind. R.*	*D.B.*	*O.B.B.*
cms . . .	30	—	20	15 to 25	—	—	25 to 30	15 to 30
inch . . .	12	—	8	—	—	—	—	—

The main reason for a greater thickness of the ballast underneath the sleepers is to avoid damages to the waterproofing due to sleeper tamping tools.

3.42) Do you consider that the casing should be protected against damage of this sort by an additional layer of concrete, ceramic tiles, or other materials?

The majority of the administrations questioned answered that the placing of a protective layer on the waterproofing is absolutely required. The undermentioned methods have been indicated:

a) concrete or mortar layers (5 cm) reinforced by a welded wire-mesh are nearly exclusively used by the following railways : L.T.R., Jap. R., D.B., Ö.B.B., Nor. R., Swed. R., T.G.O.I.;

b) furthermore, tiles and hard-burned bricks placed in bituminous or normal mortar (3 to 5 cm) are employed in case of bridges with a limited construction height or if they had to be erected in a very short time (D.B., Ö.B.B., L.T.R.);

c) a 16 % mastic asphalt (2.5 to 5 cm) sometimes with a wire-mesh reinforcing (D.B., Ö.B.B.);

d) concrete slabs placed in sand (Ö.B.B.).

3.5) When the masonry or the concrete is threatened with deterioration due to the insufficiency of the casing and when for operating reasons it is impossible to carry out essential repairs, have you done any waterproofing work to or through the soffit of the arches ? If so, with what success ?

The L.T.R. and the Irish Republic Rlys. report that pressure grouting has proved successful.

The German Federal Rlys. mention several methods :

a) The brick arch of a road underpass which had become very loose and weathered and showed considerable spalling was repaired in 1954. Cement mortar was pressed from the soffit into the structure and the soffit itself received a coat of gunite. Filter slots making use of tiles were provided in the soffit to divert the water; the slots were covered with a coat of gunite. Special boring holes direct the water from the back of the arch to the filter slots. The damaged waterproofing of the arch was not renewed. After completion of the repair work the soffit remained completely dry. New damages to the arch did not occur;

b) Another road underpass (tunnel-shaped) with a brick arch showed similar damages. Also in this case, the masonry was pressure - grouted. Subsequently, 0.5 mm copper sheets were glued (with the aid of bitumen) to the surfaces of the soffit. To protect and to keep this waterproofing in its position a 20 cm. thick concrete layer, reinforced by a welded wire-mesh, was applied underneath the soffit with the aid of a scaffolding.

In spite of the fact that it was not possible to keep the surfaces of the arch completely free of moisture it was feasible to extend the service life of this large and valuable structure by several decades.

3.6) To protect the outside surfaces of masonry work in stone, brick or concrete, do you use layers of mortar, paint or other special coatings ? If so, please state what materials are used, together with their characteristics and specify in addition under what structural and local conditions you consider their use advisable.

Six administrations do not use layers of mortar, paint or other special coatings (B.T.C., C.I. (Eire), Nig. R., EAfr. R., Jap. R., Mal. R.). Other administrations (see table next page) report on more or less satisfactory results.

3.7) What methods do you use to repair the damage listed under 3.1) above, such as, for example, grouting with cement, cutting out seams, prestressing, tie bars.

Please describe the method used on your railway.

There is no doubt that some of the undermentioned jobs — which were cited by some administrations only — are carried out much more frequently as this is stated in the answers :

separate replacement of damaged stones, new pointing of joints, renewal of the waterproofing, replacement of old masonry by new masonry or concrete plombs, temporary support of parts by

Shotcrete method, coatings with : impermeable paints or still better with linseed oil, lead, or oil paints	*A.A.R.*
Brick viaduct (damaged masonry) protected by concrete sprayed on to steel fabric. This protection failed and was removed after about 20 years.	*L.T.R.*
Coats with mineral additives.	*Nor. R.*
Coats with water-repellent paints.	*Swed. R.*
Asphaltic plaster for concrete buried in the earth. This method will be no longer applied since it is now possible to make the concrete more compact.	*T.G.O.I.*
Cement plastering of pilasters ballast walls, and tops of wing and parapet walls.	*Rhod. R.*
Weathered masonry or bricks is given a protective coating of rich mortar consisting of 1 part cement to 2 parts sand. Usually quite effective	*SAfr. R.*
Weathered surfaces are cement plastered (or cement spraying) following their thorough cleaning. Cement milk or tar coats.	*Ind. R.*
For damaged or weathered masonry surfaces only : revetment of reinforced gunite (the reinforcing steels are kept in their position by anchors) or cement plastering. Recently, the plastering or cement mortar required for the gunite process has been enriched by additives on a silicate or synthetic resin basis to considerably improve the adhesion. Surfaces exposed to blast, oil, and acids, are protected by bitumen, mineral, or « fluat » coats.	*D.B.*
Damaged surfaces : revetment of reinforced gunite; the reinforcing steels are kept in their position by anchors.	*Ö.B.B.*

wood and/or steel, arch strengthening making use of reinforced concrete or steel frames set in concrete, concrete jackets, etc. The following Table 9 shows the special methods used for this purpose.

3.81) As on most railway lines there are some old masonry bridges, have you ever thought that it is necessary to check their strength as a result of the progressive increase in loads and speeds, or do you consider that a general examination of the condition of the bridge is sufficient?

Most administrations agree that arched structures in a good condition and with a sufficient decking are capable to stand, without any difficulties, heavier loads and higher speeds. A thorough checking of the condition and regular inspections are considered as sufficient. Only the Norwegian State Rlys. are of opinion that — with increasing loads — a static examination is suitable.

The L.T.R. report that the carrying capacity of brick arched bridges has been checked by calculation in regard to the passage of abnormal indivisible road loads, in connection with the routeing of such loads.

3.82) Have you ever had to strengthen bridges simply to allow heavier loads than those estimated for at the time of construction? If so, please describe the types of reinforcement used.

Strengthening to permit heavier loads was carried out by some administrations (A.A.R., B.T.C., L.T.R., Swed. R., Jap. R.). The A.A.R. reports that piers and abutments were strengthened by placing a

TABLE 9.

Method	*A.A.R.*	*B.T.C.*	*L.T.R.*	*C.I. (Eire)*	*Nor. Rlys.*	*Swed. Rlys.*	*TGOI.*	*EAfr. Rlys.*	*Rhod. Rlys.*	*SAfr. Rlys.*	*Jap. Rlys.*	*Ind. Rlys.*	*D.B.*	*Ö.B.B.*
1. Pressure grouting	yes	yes	—	yes	—	yes	yes	yes	yes	yes	yes	yes	yes	yes
2. Cutting out seams	—	yes	—	—	—	yes	—	—	—	—	—	—	yes	—
3. Pre-stressing	—	—	—	—	—	yes	—	—	—	—	—	—	—	—
4. Tie bars	—	yes	—	yes	—	—	—	—	—	yes	—	yes	yes	yes
5. Applying gunite with and without anchoring and use of wire-mesh	—	—	—	—	—	yes	—	—	—	yes	yes	yes	yes	—
6. Colcrete process	—	—	—	—	—	—	—	—	—	—	—	—	yes	—
7. Prepact process	—	—	—	—	yes	—	—	—	—	—	—	—	—	—

thick layer of reinforced concrete around the members, carrying down to foundation where necessary.

The B.T.C. mentions that strengthening has been carried out in particular cases, in order to permit a very heavy load to travel over a bridge; the bridge is then propped temporarily by means of steel supports and timbers.

The L.T.R. report as follows: the only example which can be traced of strengthening mainly to take heavier loads, apart from the development of defects, is a strengthening of a brick arch occurring in a covered way under a highway; this was done 30 years ago by insertion of old railway rails and concrete between the arch and the highway.

In Sweden some arched structures with a thin apex have been provided with a reinforced concrete slab suspended in the ballast in order to permit a more favourable distribution of loads.

The Japanese National Rlys. report that they strengthened a concrete bridge consisting of several rigid frames with coupling beams in such a manner that simple supporting walls were erected underneath the frame cross bars and two supporting walls — being rigidly connected with each other — underneath the coupling beams. With the aid of steel wedges it was achieved that the newly erected supporting walls were fully engaged to carry the live load.

3.91) When repairing the arches of bridges necessitating the partial destruction of the masonry, what steps do you take to assure proper solidarity between the old and new masonry, and to avoid abnormal distribution of the stresses?

Six administrations (B.T.C., L.T.R., C.I. (Eire), Ind. R., D.B., and Ö.B.B.) report that damages at arches (of the kind stated in the question) were removed. The German Federal Rlys. were able to gain ample experiences with reference to the repair of arches damaged as a con-

sequence of the war events. Depending upon the importance of the repair work to be carried out one has to distinguish between :

a) the closing of small holes or damaged parts in the arch (perforations of projectiles, weathering) ;
b) the replacement of parts of the bow of the arch, and
c) the revetment or lining of entire arch sections.

Re a).

When closing minor defects the employment of embedded ties and later the pressure grouting of joints (which might have been created as a consequence of the shrinkage) in order to obtain a perfect bond and a uniform load distribution should be sufficient (B.T.C., D.B., O.B.B.).

Re b).

When replacing parts of the bow of the arch the South African Rlys. suggest to assure that the adjacent areas are not loaded. The remaining arch must be relieved and slightly lifted with the aid of a scaffolding. The German Federal Rlys. suggest that it is suitable to provide a horizontal transverse joint in the new part of the arch for the placing of pressing tools which serve — after the concrete or masonry settled and shrinked — to attain the normal pre-stressing of the arch. Following the completion of this job the scaffolding is removed, the joint is closed — from section to section — with concrete or masonry, and the lateral working joints leading to the adjacent areas are pressure grouted.

Re c).

When lining an arch by means of an additional skin the necessary bonding is achieved either by indented joints or with the aid of dowels (Ind. R.). On the occasion of the strengthening of the arches of the Berliner Stadtbahn, the reinforcing rings were extended to frame-like supporting structures and pressed from the foundations towards the old arches (D.B.).

3.92) When do you consider it advisable to undertake the partial reconstruction of masonry bridges, and when on the contrary do you think it better to demolish and completely rebuild ?

Only two administrations [C.J. (Eire), T.G.O.I.] consider a complete rebuilding generally more economical.

Nearly all other administrations state that the decision whether partial reconstruction or rebuilding has to be made depends :

upon the condition of the structure;
a comparison of the cost, and
the traffic conditions.

The opinions may be summarized as follows :

Partial reconstruction of arches is only then suitable, if it extends over a comparatively small area of major arched structures and the condition of the remaining arch, the abutments, and of the foundations is such that a long service life of the structure can be expected.

4) Inspection and maintenance of metal, masonry and concrete bridges and viaducts.

Metal bridges as well as major masonry and concrete bridges are generally periodically inspected by engineers and inspectors of the district offices or of the bridge department of the main administration of a railway. Only in some countries (U.S.A., Rhodesia, Malaya, East Africa, India, Germany, and Austria) special gangs (1 to 3 men) are at the disposal of the inspectors; the task of these workers is to examine rivets and welding seams and to perform minor repairs at steel bridges, if required.

Other administrations state that such inspections are made as and when necessary by the staff of their repair shops (Swed. R.) or of the general civil engineering or permanent way departments (Nig. R., T.G.O.I., and Jap. R.).

Smaller masonry and concrete bridges

TABLE 10. — **Size, work to be performed, and equipment of gan**

		A.A.R.	*B.T.C.*	*L.T.R.*	*C.I. Eire*	*Nor. R.*	*Swed.*
4.111	Inspection of bridges by special mobile gangs?	yes	no	no	no	no	no
4.112	Maintenance of bridges by gangs specializing *solely* in the *steel bridges* maintenance ?	yes	yes	no	yes	yes	no
	maintenance of *masonry* and concrete bridges ?	yes	no	no	no	no	no
	maintenance of *steel and masonry*/concrete bridges ?	yes	no	no	no	no	no
4.113	Inspection of overbridges by railway personnel ?	yes	yes	no	yes	no	no
4.121	Size of gangs ?	×	1 / 8	—	1 / 8	1 / 6	—
4.122	How many bridges per gang in one year?	×	×	—	1720	2100	—
4.123	With a total length of	×	×	—	×	28.5 km	
4.131	Equipment of gangs with mobile machines, tools, and implements	mason kit +	welding equipm. +	—	welding equipm. +	electric welding equipm. +	—
4.132	Are rail vehicles assigned?	yes	yes	—	×	yes	—
	Are road vehicles assigned?	yes	yes	—	×	no	—
4.211	One or more bridging workshops? . . .	several	no	no	1 central workshop	no	
4.212	Number of workers assigned to a workshop?	×	—	—	×	—	—
4.22	How are workshops equipped? With conventional machines and tools? pneumatic installations?	×	—	—	×	—	—
	For which length of bridges?	×	—	—	×	—	—
	With rail vehicles?	×	—	—	×	—	—
	With road vehicles?	×	—	—	×	—	—

Remarks : — = not applicable.
× = no data given.
\+ = air compressor as well as pneumatically operated machines and tools.

pply of materials and periodic inspections.

T.G.O.I.	*Nig. R.*	*EAfr. R.*	*Rhod. R.*	*SAfr. R.*	*Jap. R.*	*Mal. R.*	*Ind. R.*	*D.B.*	*Ö.B.B.*
no	no	yes	yes	no	no	yes	yes	yes	yes
no	yes	no	yes	no	no	yes	yes	yes	yes
no	no	no	no	no	no	no	no	no	no
no	no	no	no	no	no	no	no	no	no
no	no	no	no	yes	no	no	no	yes	yes
—	35	—	1 / 14	—	—	12	×	4 - 6	2 / 22
—	293	—	·	—	—	×	×	×	1000
·	10 km	·	·	·	—	×	×	×	×
—	+	—	electric welding equipm. +	—	—	gas welding equipm. +	electric welding equipm. +	electric and gas welding equipm. +	electric and gas welding equipm. +
—	×	—	×	—	—	yes	yes	yes	yes
—	×	—	×	—	—	no	no	yes	no
no	no	no	yes	yes	no	yes	yes	yes	yes
—	—	—	×	1 / 20	—	×	×	15 / 90	1 / 5
—	—	—	regular equipm.	regular equipm.	—	×	regular equipment	regular equipment	regular equipment
—	—	—	×	×	—	×	→ 18.3 m	→ 25 m	10 - 15 m
—	—	—	yes	×	—	×	yes	yes	yes
—	—	—	yes	×	—	×	no	yes	no

TABLE 10. — **Size, work to be performed, and equipment of g**

		A.A.R.	*B.T.C.*	*L.T.R.*	*C.I. Eire*	*Nor. R.*	*Swed.*
4.3	Total of employees used for bridge inspection?	×	1500	12	—	×	×
	for bridge maintenance?	×		50	—	×	×
4.41	Additional gangs?	yes	no	yes	yes	yes	no
4.42	For which jobs?	×	—	masonry/ concrete and wooden structures	masonry/ concrete and wooden structures	replacement of rail bearers	—
4.51	Which type of work at steel bridges is permanently carried out by railway personnel?	only if bridges are short	depending on the importance and difficulty of the job	paint repairs	repairs	all repairs	replacement of rivets
	By contractors?	generally		new constructions	new constructions	paint work	other jobs
4.52	Which type of work at masonry or concrete bridges is carried out by railway employees?	generally	works carried out while operating is not interrupted	depending on cost and workers available	repairs	all works	pressure grouting of cement
	By contractors?	special jobs	all other works		new constructions	—	other jobs
4.61	Are materials required for repairs kept in depot? or	no	small stocks	no	no	no	paints rivets
	bought as required from private industry?	yes	yes	yes	yes	yes	yes

Remarks : — = not applicable.
× = no data given.
+ = air compressor as well as pneumatically operated machines and tools.

ly of materials and periodic inspections *(continued)*.

G.O.I.	Nig. R.	EAfr. R.	Rhod. R.	SAfr. R.	Jap. R.	Mal. R.	Ind. R.	D.B.	Ö.B.B.
— —	× 12 / 200	1 / 1 —	1 / 2 330	45 150	30 / 9 54	1 / 2 60	× ×	1000	18 / 28 280
no	no	no	no	no	no	no	no	no	no
—	—	—	—	—	—	—	—	—	—
ispec- tions amina- on of ivets	all works	all works	minor jobs	minor jobs	span smaller than 16 m	maintenance	assembly works	maintenance	minor jobs
all vorks	—	—	major jobs	major jobs	span larger than 16 m	new constructions	new constructions	new constructions	major jobs
ispec- tions	all works	all works	—	minor jobs	—	maintenance	repairs	—	—
all najor jobs	—	—	—	major jobs	all works	new constructions	new constructions	all works	all works
no	steel sections	no	yes	yes	some	only a few	steel sections rivets	for one year	yes
yes	yes	yes	special parts	no	yes	yes	yes	for masonry and concrete bridges	no

TABLE 10. — **Size, work to be performed, and equipment of g**

		A.A.R.	*B.T.C.*	*L.T.R.*	*C.I. Eire*	*Nor. R.*	*Swed*
4.62	Are supplies for works done by contractors furnished from a depot of the Administration?	no	no	only second hand material	no	no	rus protec pai
	Furnished by the contractor?	yes	yes	yes	yes	yes	yes
4.7	Are steel spans repaired at the site? . . .	yes	yes	yes	yes	depending on the importance	yes
	In railway-owned workshop?	no	no	no	no	yes	yes
	In a private workshop?	no	no	no	no	yes	no
4.8	Do maintenance gangs work in accordance with a predetermined programme?	yes	yes	no	no	no	yes
	As necessary?	no	no	yes	yes	yes	no
4.911	Periodical bridge inspection?	different	yes	yes	yes	yes	yes
4.912	Difference between summary inspection and thorough examination?	different	yes	no	no	yes	yes
4.913	Intervals (in years) between summary inspection?	different	1 / 2	—	—	1	> 15 < 15
	Thorough examination?	different	3	3	3	6	3 or

Remarks : — = not applicable.
× = no data given.
+ = air compressor as well as pneumatically operated machines and tools.

as well as culverts are generally inspected and controlled by the civil engineering staff of the local offices.

Only six administrations state that they also inspect structures bridging tracks (road overpasses).

The methods introduced for day-to-day maintenance are also very different. Several administrations have no special maintenance gangs (L.T.R., Swed. R., T.G.O.I., EAfr. R., SAfr. R. and Jap. R.). The works necessary are performed either by contractors or by railway employees *being not* exclusively specialized in bridge maintenance (L.T.R., Swed. R., T.G.O.I., SAfr. R. and Jap. R.).

The remaining 10 administrations report that they have special bridge maintenance

ply of materials and periodic inspections *(continued)*.

.G.O.I.	Nig. R.	EAfr. R.	Rhod. R.	SAfr. R.	Jap. R.	Mal. R.	Ind. R.	D.B.	Ö.B.B.
no	yes	yes	×	yes	cement	×	cement steel paints	cement tiles paints aggregates	yes
yes	no	no	×	no	yes	×	yes	yes	no
yes	yes	yes	yes	yes	yes	yes	yes	depending on the importance of the job yes	yes
no	no	no	no	no	no	no	yes	yes	yes
no	no	no	no	no	no	no	no	yes	yes
—	yes	no	no	no	—	yes	—	—	yes
—	no	yes	yes	yes	—	no	yes	yes	yes
yes	yes	yes	yes	no	yes	yes	yes	yes	yes
yes	no	yes	no	no	yes	yes	yes	yes	yes
1	prior and subsequent to the raining season	1 - 2	—	as required	2	2	1	3	2
3		3	1		as required (natural phenomena)	1	5 span > 15 m	6	6

gangs; however, these gangs are nearly exclusively specialized in steel bridge maintenance. Masonry and concrete bridges are also maintained by contractors or by railway employees of the field offices not specialized in bridge maintenance. Only a few American railways have gangs being specialized in the maintenance of masonry and concrete bridges. There are also some railways in the U.S.A. the gangs of which are specialized in the maintenance of *all* existing bridges.

The South African Rlys. have a number of mobile bridge gangs but they do not carry out inspections or routine maintenance. They exist for the purpose of bridge erection and construction, heavy maintenance repairs, and bridge strengthening.

Further information concerning the size, the works to be done, the equipment of the gangs, the supply of materials, and the inspection periods are to be seen from Table 10.

APPENDIX 1.

JAPANESE N.R.

Reference.

A simplified formula for limiting speed with respect to the plate girder usually adopted by J.N.R.

The field investigation on the vibrational characteristics of girder has revealed that the impact increases roughly proportionally to the speed and reaches its maximum value i_o at a resonance speed of locomotive V_o with respect to the bridge.

Then, assuming that an impact of somewhere around 15 % always happens due to the effect of rail joint and others, no matter how low the speed is, a BCM line has been drawn as shown below as the speed-impact curve for a bridge whose degree of safety has been lowered.

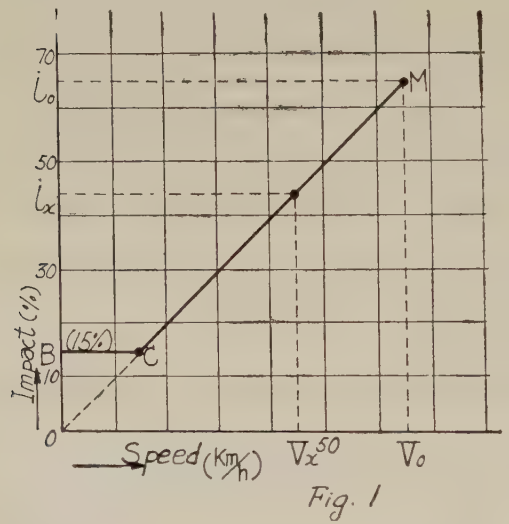


Fig. 1

As the second procedure, the allowable impact i_x for the bridge in question is calculated and V_x which corresponds to i_x is found through the curve shown above. V_x is expressed in a round number by 5 km/h discarding odds, which is specified as the speed limit for the corresponding i_x.

(1) Calculation of the maximum impact :

$$i_o = 0.7 - \frac{L^2}{4\,000} \quad \text{for } L \leqslant 30 \text{ m}$$

$$i_o = \frac{10}{L} + 0.14 \quad \text{for } L > 30 \text{ m}$$

where L ——— Effective span of bridge (m).

(2) Calculation of resonance speed V :

$$V_o = 3.6 \times \pi \varphi \sqrt{\frac{310}{\delta_l + d}} \text{ (km/h)}$$

where :

$\delta_l, + d$ ——— The deflection due to the dead and live loads in cm, the impact being ignored.

A practical formula of $\delta_l + d$ for a plate girder is given by :

$$\delta_l + d = \frac{55\ L^2}{48\ EI} (M_L + M_D);$$

φ ——— Diameter of driving wheel (m);

E ——— Young's modulus of the material (kg/cm²);

I ——— Moment of inertia (cm⁴);

M_L ——— Moment due to live load (kg-cm);

M_D ——— Moment due to dead load (kg-cm).

(3) The allowable impact i_x for the bridge in question :

$$i_x = (1 + i_o)\ S - 1$$

where :

S ——— Factor of capacity of the old bridge.

Speed limiting with respect to trusses is determined after precise investigation and special examination by experts of the Head Office or Railway Operating Division Office.

APPENDIX 2.

DEUTSCHE BUNDESBAHN (fig. 2).

Repair of a welded rigid frame with two hinged supports at the subway in Duisburg Main Passenger Station.

A frame (St 37 SM) of the subway at the above mentioned station was hit by a bomb at a point near the northern frame corner. As a consequence, the frame fractured in all cross-sectional areas. Due to the grate effect of the girders belonging to the steel structure (width 9.30 m) between platforms 2 and 3 the frame did not collapse, but was maintained in its original position by the adjacent frames and the cross girders (see drawing).

It was impossible to remove this damage by the insertion of riveted flange and web plate parts since the cross section would have been too much weakened on account of the rivet holes, the highly strained frame corner would have been subjected to undue stresses, and the bearing of the troughs of the deck construction would have been difficult.

Following its supporting and the removal of the damaged part of the horizontal main bar the frame was repaired by welding.

The thickness of the flange plates is 65 mm while that of the web is 25 mm. The welding is of particular importance since the operations required had not only to be performed on very thick plates and under extraordinary difficulties — due to the uncomfortable position of the welders, but also because all welding joints are located near the frame corner, and one flange plate welding joint had even to be arranged in a curve and since the frame had permanently to remain, during the execution of this difficult job, in its original position, i.e. in connection with the double tracked structure consisting of four frames, cross beams, and a floor slab. Thus considerable dismantling expenditures could be saved.

The installation of the individual parts was commenced at the tension flange (at the top). The new flange plate piece — 460 × 65 = 1 080 mm long — was inserted and welded — by means of two cross seams in several layers — to the adjacent flange parts. Since the frame shaft was so suspended that it could swing freely within the frame plane, it was able to follow the effect of the aftershrinkage in the upper flange plate. Test welds revealed that, because of the thickness of the flange plates (65 mm), tulip-shaped seams caused heavy one-sided shrinkage of the test specimen. Consequently, the application of tulip-shaped seams was dispensed with.

Following the welding of the upper flanges the compression member (at the underside), which had to be replaced, was inserted at the soffit of the frame corner and — by simultaneously pressing on the frame shaft — welded together.

The most difficult part of this job was the welding of the 1 953 mm long web plate part the dimensions of which were so selected that they exceeded those actually required. Prior to the insertion of the plates and during the welding of the vertical seams, the horizontal bar flanges were heated with the aid of a torch with a special head until a temperature of 150 centigrades was reached; during this process the flange plates expanded by approximately 3 mm. As soon as this condition was achieved the web plate was fitted in, and both vertical seams were subsequently butt-welded. The extent of expansion of the flange plates corresponded to the presumable shrinkage of these seams. Thereafter, the neck seams were welded.

Finally, the reinforcing plates — 120 × 20 — were welded to the web and pressure flanges, and the repaired frame was connected to the deck construction by welding. The butt seams of the flanges were ground plane to obtain maximum fatigue limits and X-rayed.

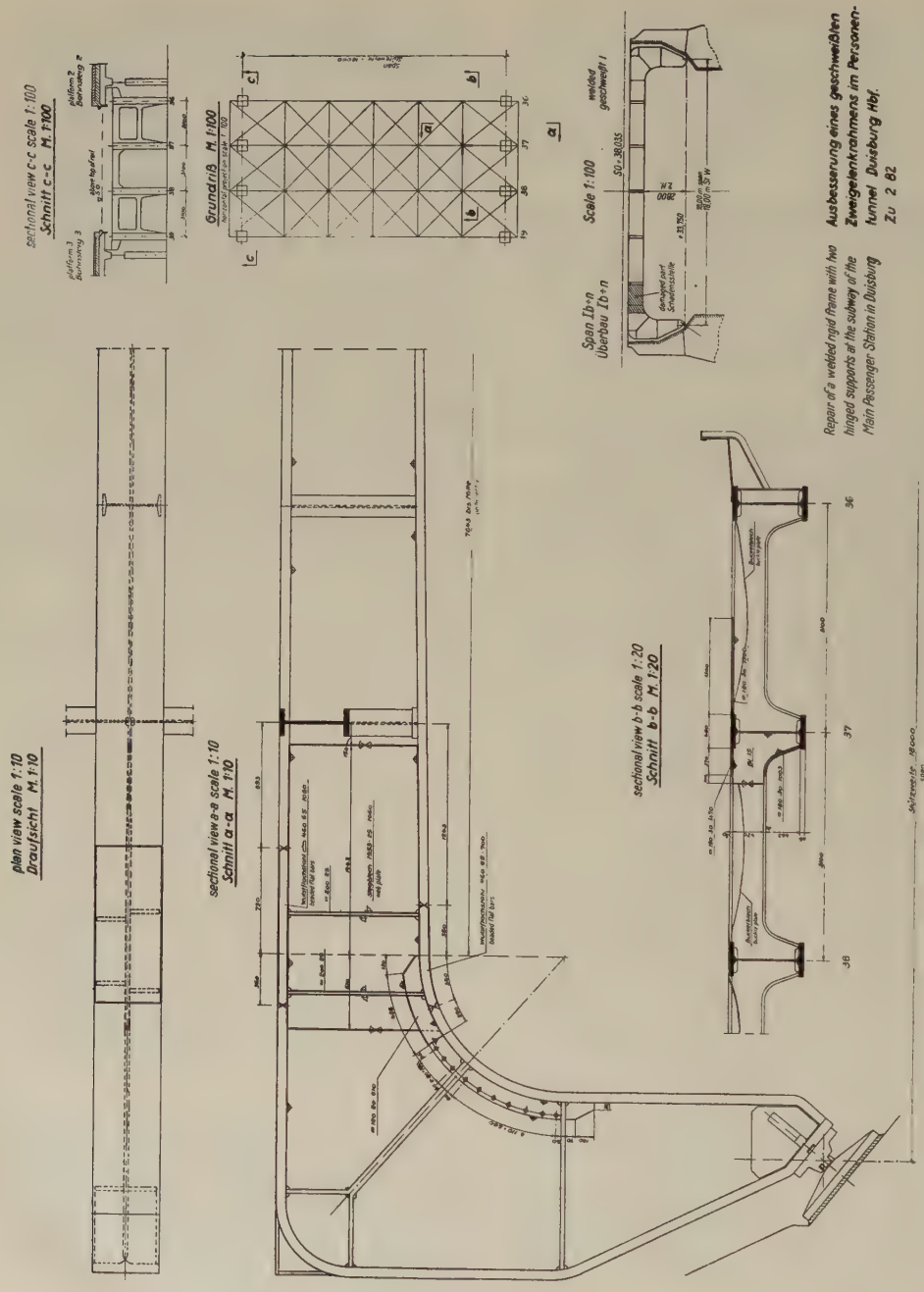

sectional view c-c scale 1:100
Schnitt c-c M. 1:100
Grundriß M. 1:100
Span 1b-n
Überbau 1b-n
Scale 1:100
plan view scale 1:10
Draufsicht M. 1:10
sectional view a-a scale 1:10
Schnitt a-a M. 1:10
sectional view b-b scale 1:20
Schnitt b-b M. 1:20
Repair of a welded rigid frame with two hinged supports at the subway of the Main Passenger Station in Duisburg
Ausbesserung eines geschweißten Zweigelenkrahmens im Personentunnel Duisburg Hbf.
Zu 2 82

Fig. 2

APPENDIX 3.

JAPANESE N.R.

(1) Looseness of eye-bar of pin-connected truss.

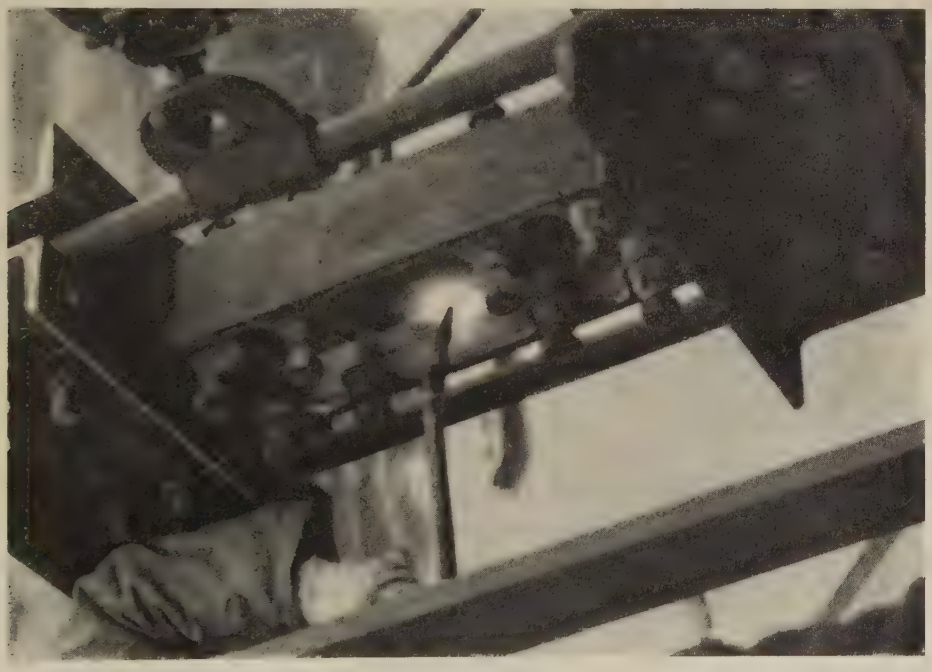
Looseness of the diagonal eye-bars of the pin-connected truss, whose span ranges from 45 m to 90 m, and which is used in number on the JNR main lines, becomes serious on account of age. To normalize and repair such truss, a work method called « shortening of eye-bar » has been practised since 1952. That is to say that a shortening device is attached to the loose eye-bar, and after heating the eye-bar, it is shortened by an upsetting process. This process will be repeated until the calculated regular stress, which will be found by observing the frequency of eye-bar, is resumed.

This process was applied during a period from 1952 to 1955 to 745 eye-bars of about 80 spans of truss which showed a most critical looseness, of the total of 150 spans. At the same time, the turn-buckles that were found loose were re-fastened.

(2) Cracks in the rail bearer of trough girder.

Upon checking over the entire system in 1948, cracks were found in the rail bearer in 260 spans of the total of 2 655 spans that were inspected.

This was caused by the fact that the rail was rigidly fastened to the bearer, and therefore, the deflection of rail affected on the bearer, producing positive and negative bending moments at its root, which in turn caused the failure due to fatigue. Consequently, it has been so improved



Photograph No. 1.

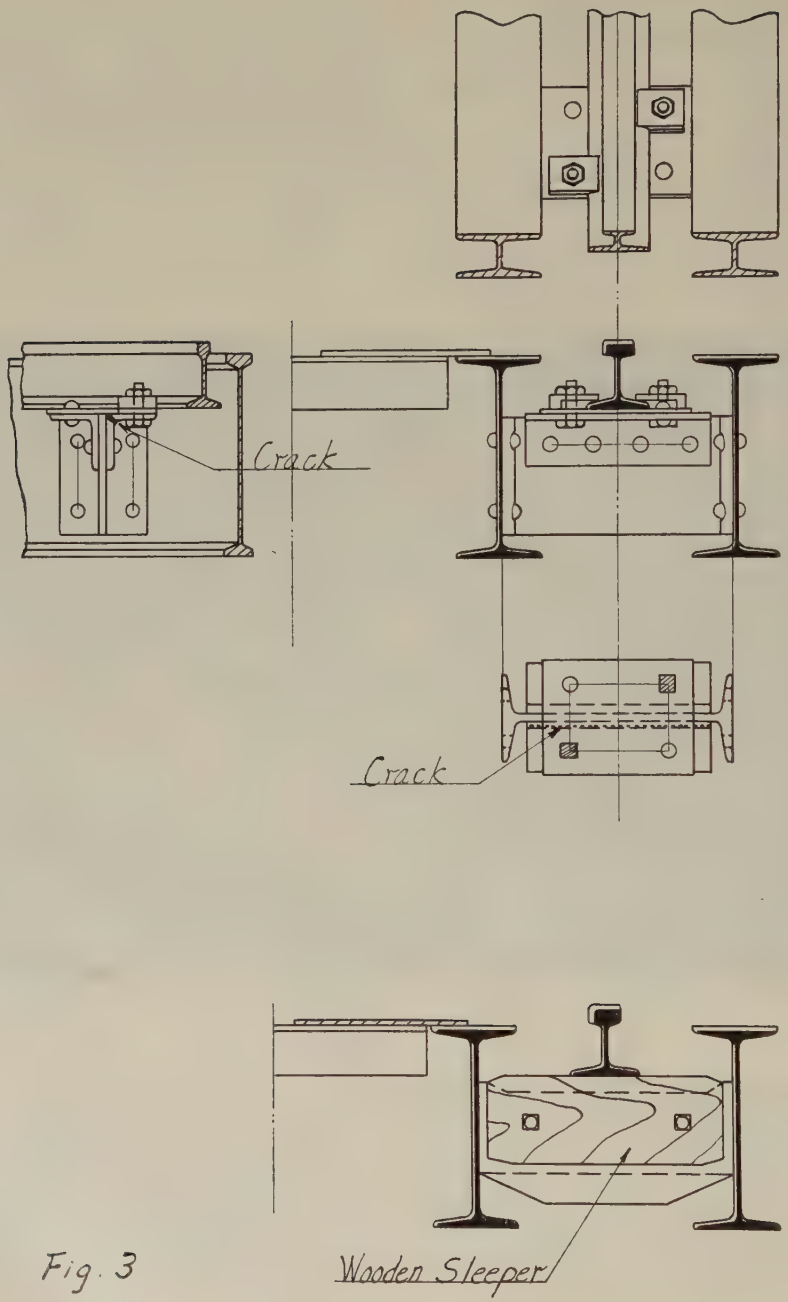


Fig. 3

that the rail rests directly on a cross wooden sleeper.

(3) Eccentricity of the web of lattice girder.

Inasmuch as the lattice girder has no sway bracing, the vibration of the upper flange is larger than that of the lower flange, and the lateral torsion is large. Therefore, the sway bracing has been attached.

lattice girder of 22.3 m span has been replaced.

(4) Crack at the bearing part of the lower flange of plate girder.

In the bed-and-sole plate type of support, the manner of support becomes an edge-support on account of the deflection of girder, concentrating the stress at the lower flange plate or angle of the main girder, which causes the crack. Besides,

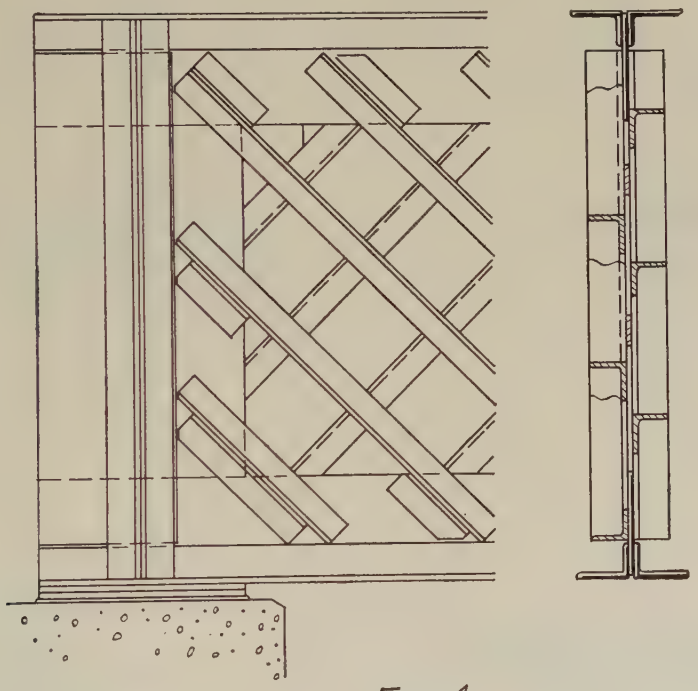


Fig. 4

However, the eccentricity of the connection of web-members and flange with respect to the web-members causes a bending stress in the web-members, and an actual survey has revealed that inasmuch as the curvatures due to bending of both tension and compression members turn to the same direction, they act together resulting in a large secondary stress. As a result, the

because this is the part which is most easily corroded, a stiffener has been inserted after the crack has been repaired.

(5) Rolling off of the rollers of the truss shoe.

The roller bearing of old truss has a cage-plate which keeps the rollers in position, but not a fixture which prevents

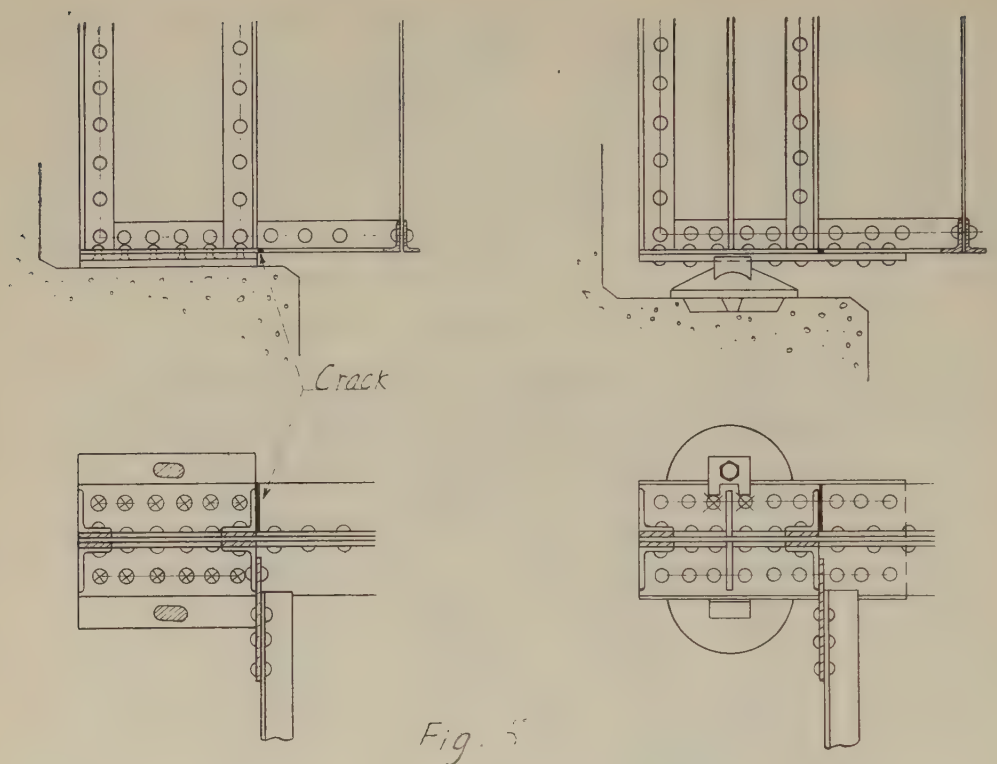


Fig. 5

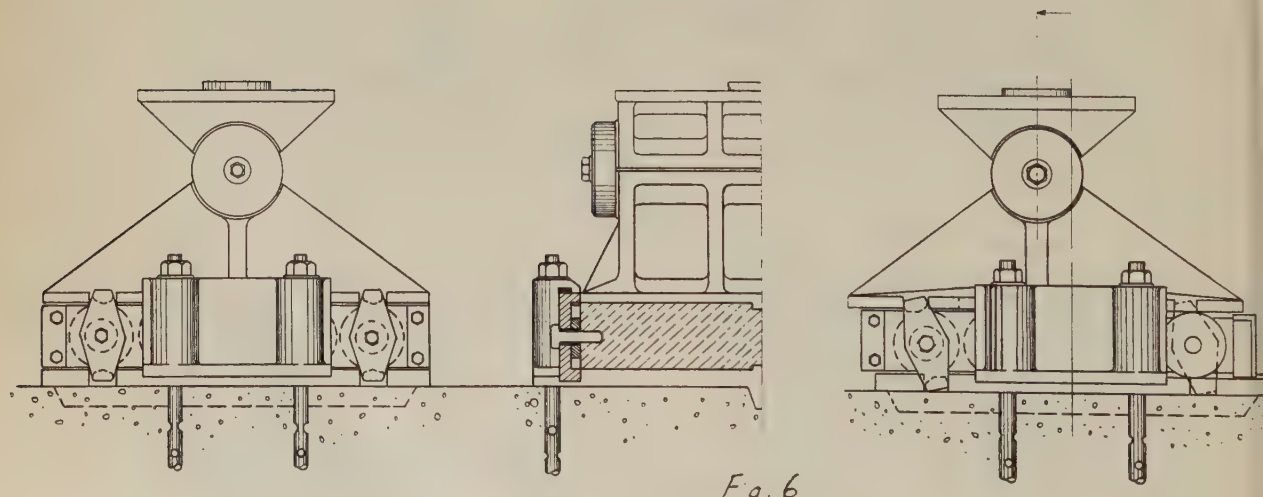


Fig. 6

Section a-a

Existing Rivet ϕ25
Bolt for Strengthening ϕ25

Fig. 7

the whole rollers from rolling out, nor a device which keeps the axis of roller and that of bridge perpendicular to each other. As a result, there have been many cases where the rollers generally roll out toward the direction of the center of span and the perpendicularity of their axes to the bridge axis becomes out of order, thus losing the function as the roller bearing.

For those rollers that have been found in a rather serious condition, the truss has been jacked up, the rollers have been brought back to the normal position and certain metal fittings have been applied as shown in the sketch. Thus the rolling out of rollers has been prevented and the perpendicularity has been resumed.

(6) Hinge of cantilever girder.

Inasmuch as it has been revealed that, the shearing stress of the rivets at the hinged part of the cantilever bridges in the urban lines built in 1900 → 1910 inclusive, ranges from 1 050 to 1 100 kg/cm² under the present load condition, such bridges have been strengthened by increasing the number of rivets or by additional bolts, keeping the shearing stress at 750 kg/cm² or less.

APPENDIX 4.

DEUTSCHE BUNDESBAHN (fig. 15).

The spans of the bridge over the river Neckar on the Mannheim-Frankfurt/Main line — which were manufactured in 1898 — were strengthened in 1926 for « train load E ». The main girders consisted of parallel-lattice girders with ascending and descending diagonals. The span widths amounted to 56.0, 76.0, and 56.0 m; the old system height amounted to 7.0 m, and the width of bays to 4.0 m.

The strengthening was accomplished by placing arches on the top boom (see drawing). Moreover, several lattice girders of the main girders had to be reinforced. To achieve satisfactory interaction between old and new components and to secure

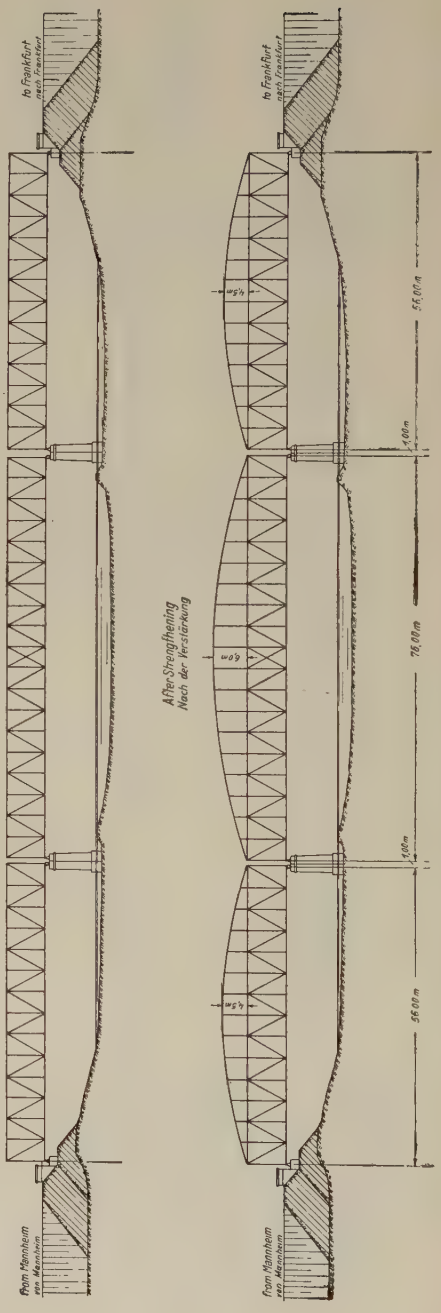

Strengthening of spans for « Train Load E ». Verstärkung der Überbauten für Lastenzug E im Jahr 1926.
Overall view downstream Gesamtansicht von Unterstrom.
Prior to Strengthening Vor der Verstärkung
After Strengthening Nach der Verstärkung
To Frankfurt nach Frankfurt
From Mannheim von Mannheim
56.00 m
76.00 m
56.00 m

Fig. 15. — Deutsche Bundesbahn. Bridge over the river Neckar near Mannheim.

that the reinforcing members carried part of the stresses due to the dead load, corresponding pressure forces were initiated (between 0 and 320 tons) with the aid of pressing tools placed on the top of the arches so that the stress existing on account of the proper weight in each bar to be strengthened was decreased to 0.

Following the execution of the strengthening the horizontal pressure required for the entire system was generated, with the aid of pressing tools, in the arches and they were closed. The horizontal pressure was calculated with :

150 tons for the centre span and

130 tons for both side spans.

APPENDIX 5.

JAPANESE N.R.

In Japan, the weight of locomotive has considerably increased as shown in the annexed diagram, and consequently many girders have become overloaded under the present load condition, for which various methods of reinforcement have been studied and carried out.

(1) Reinforcement of trussed beam type.

In this type of reinforcement, certain tension members and struts are additionally attached to the existing plate girder to form a trussed beam as shown in the photograph.

Generally speaking, the king-post type is applied to the girder of 6.5 m span and the queen-post type, to the girder of 6.5 m → 22 m span for the reinforcing purpose. By means of these methods the strength of

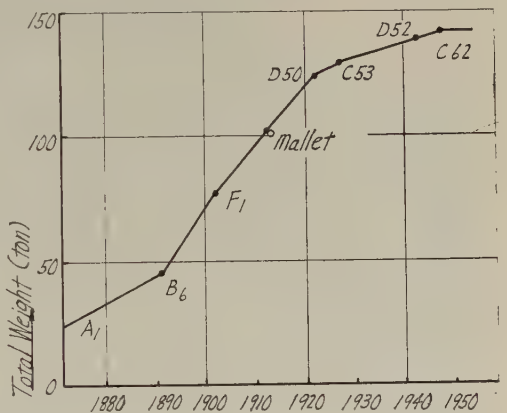


Fig. 8

6.5 → 22 m girder can be increased by 40 → 150 %. The reinforcing members, in the case of king-post type, are tightened by the wedge at point B, while the stress is being measured, and in the case of queen-post type, the reinforcing members

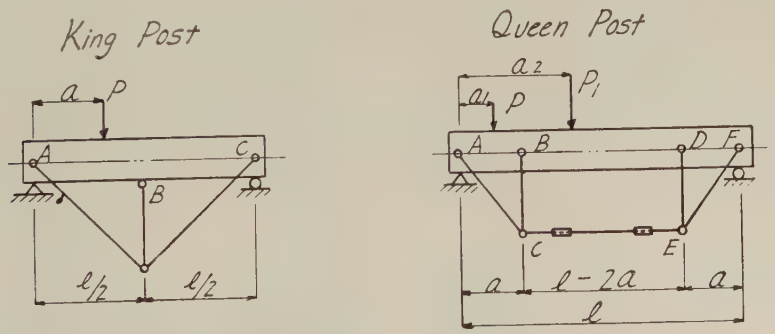


Fig. 9

Photograph No. 2.

are tightened by means of the turnbuckles which are installed between C and B as shown in the sketch, while the stress is being measured.

In both cases the reinforcing members are tightened until the stress reaches a specified magnitude, so that the dead load may be also shared by them.

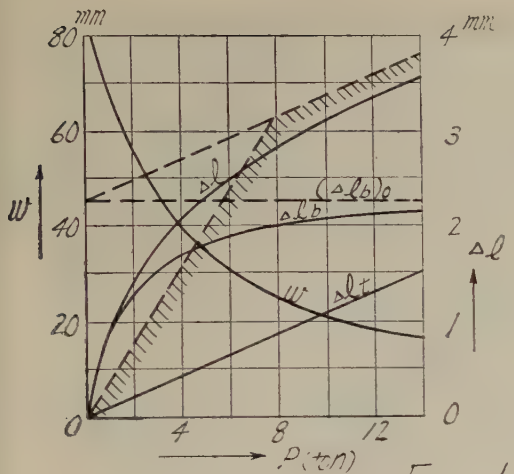
The reinforcement of trussed beam type that is applied to the plate girder will not develop the expected effect, unless an adequate initial tension is given to its horizontal member as shown in the diagram.

In the case of especially long Fing bar, the relation between tension and elongation is not linear, but is expressed by $\triangle l$ curve, being affected by the deflection and therefore, strictly speaking, the theory of least work cannot be applied, and it is considered, however, that the theory can be approximately applied only when the tension is large and the deflection becomes practically negligible.

There have been some cases where the forged joint of turnbuckle failed or the effect of reinforcement was unreliable due to the deflection, and recently such girders are being replaced.

(2) Parallel reinforcement.

A certain old girder of practically similar type is attached in parallel to either side of the existing girder as shown in the sketch in such a way that the additional girders share the load. The increase of strength at the center of span by this method is 50 % when there is only one intermediate joint, 75 % when two joints and 90 % when three joints. It is difficult



$\triangle l_t$ ——— Elongation due to tension.

$\triangle l_b$ ——— Elongation due to the change of deflection of horizontal member.

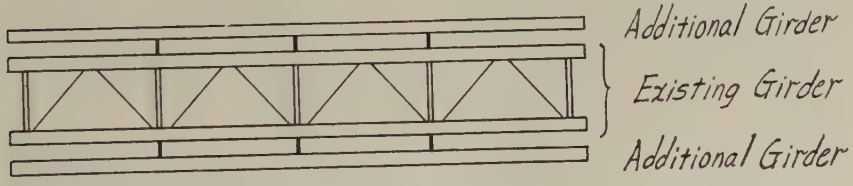
$\triangle l$ ——— Total elongation of horizontal member.

$\triangle l = \triangle l_t + \triangle l_b$

ω ——— Deflection.

P ——— Horizontal tension.

Fig. 10



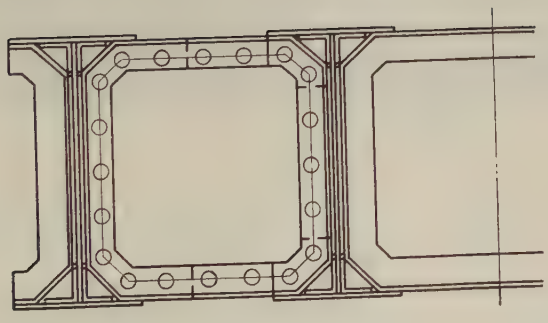
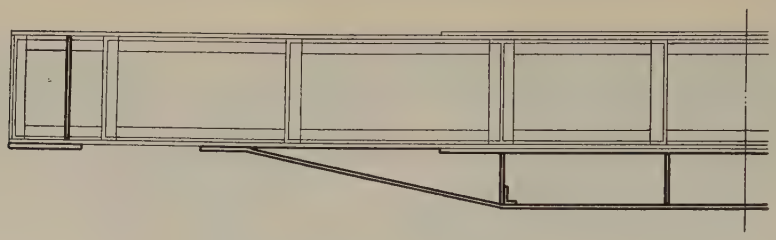


Fig. 11



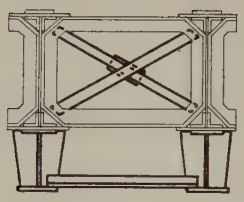


Fig. 12

Photograph No. 3.

to keep the eight bearing points on one plane, and this method has been in practice for the last 30 years.

(3) Reinforcement by arc-welding.

a) T-type reinforcement.

A piece of T shape is welded to the lower flange of the existing girder as shown in the sketch in order to increase the height of girder. This method is used when there is enough space underneath the girder and the upper flange need not be reinforced. This method has been satisfactorily practised since about 26 years ago.

b) Reinforcement by jointly using channel and T.

In the T type reinforcement, the upper flange is left intact as mentioned in a) above, and therefore, as years go by the corrosion becomes so serious that it causes occurrence of crack. To prevent this, a channel section is attached to the upper flange and a T section to the lower flange. This method has been in practice for the last 26 years, being economically advantageous.

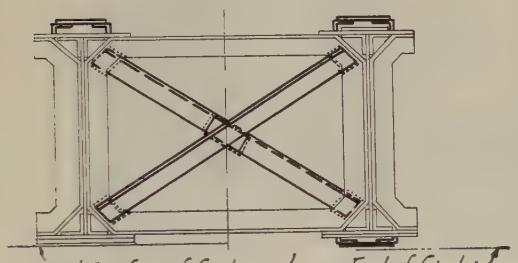


Fig. 13

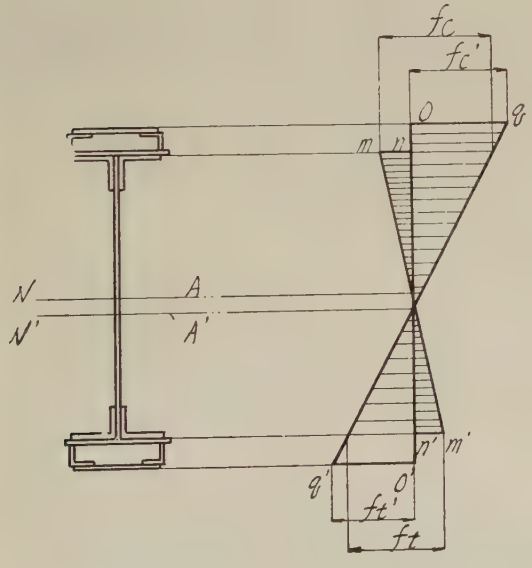
c) Channel type reinforcement.

Channel type reinforcing members are welded on both upper and lower flanges of the existing girders in order to increase the cross sectional areas of flanges. This method has been in practice also for the last 26 years.

In the case that a bridge is reinforced with channels while it is in position, the strength of the girder is limited by the bending stress in the existing members, because the reinforcing members receive the live and impact loads only as shown in the sketch, and a stress as high as the allowable stress generally is not allowed in the new members.

The increase of strength due to the reinforcement by welding is somewhere around 80 % in maximum.

It is considered that the reinforcement by welding lasts for fairly long time so long as the corrosion of the base metal does not develop, and the method is still in use at present.



m n m'n' Stress due to dead load
o q o'q' " live load and impact
fc ft Stress of the existing cross section
fc' ft' Stress of the reinforced cross section

Fig. 14

Photograph No. 4.

(4) Reinforcement by rivets.

In the case of wrought iron girder of poor weldability in a deck plate girder, the rivets of flange are removed and the corroded cover plate is replaced with a new one or an additional cover plate is attached for reinforcement.

There is an example that a Warren truss of Pownall type was reinforced turning it into Langer truss as shown in the photograph. The increase of strength is 150 %.

[621 .3 : 651]

INTERNATIONAL RAILWAY CONGRESS ASSOCIATION

17th. SESSION (MADRID, 1958).

QUESTION 7.

Advantage of the use of high speed electronic apparatus for certain administrative works such as :

1) the making out of pay slips;

2) traffic and stores accounts;

3) the checking of the movement of empty and loaded freight wagons, thereby improving the distribution of rolling stock;

4) compiling more rapidly already existing statistics, thus having also the possibility of preparing new ones.

REPORT

(Austria, Belgium and Colony, Bulgaria, Cambodia, Czechoslovakia, Denmark, Ethiopia, Finland, France and French Union, Western Germany, Greece, Hungary, Indonesia, Italy, Lebanon, Luxemburg, Netherlands, Poland, Portugal and overseas territories, Rumania, Siam, Spain, Switzerland, Syria, Turkey, Viet-Nam and Yugoslavia),

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de la Société Nationale des Chemins de fer Français, (Paris).

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INTRODUCTION.

1. Administrations consulted in connection with the present report.

In order to secure the widest possible basis for the preparation of the Reports on Question 7 (Section IV), a detailed questionnaire was worked out at a meeting held in Berne between the Reporters and the Secretariat of the Association. The questionnaire was sent out to the following Railway Administrations and associated organisations :

— *Member Administrations :*

Western Germany.

Deutsche Bundesbahn.

Austria.

Austrian Federal Railways (Ö.B.B.).

Belgium and Colony.

a) Belgium :

Société Nationale des Chemins de fer Belges;

Société Nationale des Chemins de fer Vicinaux;

Compagnie Générale d'Entreprises Electriques et Industrielles « Electrobel »;

Railways Economiques de Liège-Seraing et Extensions;

Compagnie Belge de Chemins de fer et d'Entreprises.

b) Colony :

Chemins de fer du Bas-Congo au Katanga;

Chemins de fer du Congo Supérieur aux Grands Lacs Africains;

Chemins de fer Vicinaux du Congo;

Office d'Exploitation des Transports Coloniaux (OTRACO).

Bulgaria.

Bulgarian State Railways.

Denmark.

Danish State Railways;
Private Railway;
East of Seeland Railway;
Lolland-Falster Railway.

Spain.

Red Nacional de los Ferrocarriles Españoles (R.E.N.F.E.);
Catalanes Railway Company.

Finland.

Finnish State Railways.

France and French Union.

a) France :

Société Nationale des Chemins de fer Français;
Chemins de fer Départementaux;
Société Générale des Chemins de fer Economiques;
Chemins de fer Economiques du Nord;
Régie Autonome des Transports Parisiens;
Chemins de fer Secondaires du Nord-Est;
Compagnie Générale de Voies Ferrées d'Intérêt local.

b) Other territories of the French Union :

Africa.

Chemins de fer Algériens;
Chemins de fer de Gafsa;
Compagnie Fermière des Chemins de fer Tunisiens;
Chemins de fer de l'Afrique Equatoriale Française et du Cameroun;
Chemins de fer Coloniaux de l'Afrique Occidentale Française et Togo;
Chemin de fer Franco-Ethiopien de Djibouti à Addis-Abeba;
Chemins de fer de Madagascar;
Chemins de fer du Maroc;
Chemins de fer de la Méditerranée au Niger.

Asia.

Chemins de fer Royaux du Cambodge;
Régie des Chemins de fer du Viêt-Nam.

Greece.

State Railways;
Chemin de fer Pirée-Athènes-Péloponèse.

Hungary.

State Railways.

Indonesia.

State Railways.

Italy.

State Railways;
Mediterranean Railways;
Railway and Tramway National Company;
North of Milan Railways;
Ferrovie del Sud-Est;
S. A. Torinese Tranvie Intercomunali;
Venitian Company for the Building and Operating of Secondary Railways in Italy;
Brescia Electric Tramways.

Luxemburg.

Société Nationale des Chemins de fer Luxembourgeois.

Netherlands.

Netherlands Railways.

Poland.

State Railways.

Portugal and Overseas territories.

a) Continent :
Portuguese Railways.
b) Overseas territories :
Angola Railways;
Benguela Railways;
Mozambique Railways.

Rumania.

State Railways.

Switzerland.

Swiss Federal Railways;
Bernese Alps Railways;
Rhaetian Railway;
Viege-Zermatt Railway;
Yverdon-Sainte-Croix Railway;
Fribourgeois Railways;
Emmental-Burgdorf-Thun Railway.

Syria.

State Railways;
Damas-Hama and Extensions Railway.

Czechoslovakia.

State Railways.

Turkey.

State Railways.

Yugoslavia.

State Railways.

— *Affiliated Organisations :*

Compagnie Auxiliaire Internationale de Chemins de fer;
Compagnie Internationale des Wagons-Lits et des Grands Express Européens;
Deutsche Schlafwagen- und Speisewagen Gesellschaft;
Federazione Nazionale Imprese Trasporti;
Office Central des Transports Internationaux par Chemins de fer;
Union Internationale des Chemins de fer;
Union des Voies Ferrées;
Union d'Entreprises Suisses de Transport.

2. Definition.

When the questionnaire was prepared, it was deemed absolutely necessary to provide a precise definition of « high output electronic computers for use in administrative work » which we had called « Ordinateurs » (i.e. « computers ») for short.

In the French version of this report, we have used the term « Ensemble Electronique de Gestion » or « E.E.G. » for short, which seemed to us to represent a satisfactory translation of the accepted American term « Electronic Data Processing Machine », or « E.D.P.M. » for short. Incidentally, the term « Ordinateur » has already been claimed as a proprietary name by one of the leading manufacturers.

The following definition was suggested : « *An electronic data processing machine is made up of electronic units operating at high speed, and of high capacity. It can perform any calculation or logical operation (comparison), working from a stored programme.* »

Our inquiry also included certain *electronic machines for special purposes* such as seat reservations, automatic accounting, etc.

On the other hand, and this has been pointed out by certain Administrations in their replies, we did not deal with electronic computers for arithmetical or scientific work. In fact, the wording of the Question is merely concerned with problems of administrative work. However, owing to the close kinship between electronic data processing machines and electronic computers, the latter will also be mentioned on several occasions, and our questionnaire also envisaged the use of electronic data processing machines for the handling of problems of a scientific character.

3. Preliminary analysis of replies received.

Up to now, replies have been received from 45 Railway Administrations. Among these, 29 stated that they were unable to provide the information asked for, essentially for the following reasons :

— the advent of electronic data processing machines was still of such recent date that they had not yet been able to complete the preliminary studies;

— many of these Administrations were of the opinion that their size and operating characteristics did not appear to justify the use of such apparatus.

Among the 16 Administrations from whom a positive reply was received, the following :

— two Administrations had already placed an order for such equipment :
  — France — S.N.C.F. : one I.B.M. Type 650 Computer, to be delivered in 1958, and one Bull Gamma 60 machine to be delivered in 1960;
  — France — R.A.T.P. : one I.B.M. Type 650 Computer, to be delivered in 1958;

— two Administrations were about to place an order :
  — Belgian Congo — OTRACO : (equipment not specified);
  — Finland : reservation of one I.B.M. Type 650 Computer.

The following twelve Administrations stated that they were still in the stage of preliminary studies, or furnished useful information about the present position concerning the mechanisation, by means of punch-card methods, of their administrative work :

— *German Federal Republic :* Deutsche Bundesbahn;

— *Austria :* Oesterreichische Bundesbahnen;

— *Belgium und Colony :*
  Société Nationale des Chemins de fer Belges;
  Société Nationale des Chemins de fer Vicinaux;
  Chemins de fer du Bas-Congo au Katanga;

— *Spain :* Red Nacional de los Ferrocarriles Españoles;
— *France and French Union :* Chemins de fer de Madagascar;
— *Italy :* Italian State Railways;
— *Netherlands :* Netherlands Railways;
— *Poland :* State Railways;
— *Portugal :* Portuguese Railways;
— *Switzerland :* Swiss Federal Railways.

At this point, we should like to express our vivid thanks to all the Administrations concerned for their kind collaboration which has enabled us to prepare the foundations for this report.

Finally, the International Union of Railways have indicated that they have undertaken a study of the applications of electronic data processing machines and of the services which these machines might be able to render to the Railway Administrations.

4. General outline of the present report.

As the replies show, none of the Administrations consulted is in fact using electronic data processing machines at present. This is not surprising. The machines concerned have only been available for a few years. It was in 1951 that the first Univac I of Sperry-Rand was taken into operation by the American Government Bureau of Census at Washington, and it was only after that date that sufficient detailed information became available outside the United States, the country in which, up to the present, nearly all manufacturers and users of these machines are domiciled.

It will therefore still take several years before the first users will be able to draw up a balance sheet of their experience. In the circumstances, it seemed to us that the present preoccupations of the Railway Administration would be best served by devoting a major part of this Report to a fairly detailed description of the general characteristics of electronic data processing machines and of the problems inherent in their use.

5. Bibliography.

Apart from the replies furnished by the Administrations, our principal sources of documentation for the compilation of this report were these :

— Automation by John DIEBOLD (French translation published by Dunod, Paris, 1957);
— Electronic Computers and Management Control, by George KOZMETSKY and Paul KIRCHER (Mac Graw-Hill Book Company, 1956);
— Office Automation — Integrated and Electronic Data Processing, by R. HUNT BROWN (Automation Consultants Inc. New York, 1956);
— Office Automation Applications, by R. HUNT BROWN (Automation Consultants Inc., New York, 1957);
— Various specialized technical and railway journals;
— Documentation provided by different manufacturers.

CHAPTER I.

GENERAL CHARACTERISTICS OF ELECTRONIC DATA PROCESSING MACHINES.

1.1. Standard punch-card systems and electronic data processing machines.

After defining « Electronic Data Processing Machines », and before examining their characteristics, it appears to be necessary to elucidate clearly the difference between electronic data processing machines and standard punch-card systems. Not only, the speed of punch-card machines remains limited by the presence of mechanical parts; but in particular, there are intrinsic limitations to the use of punch-card systems. *These can only deal with factual data which must all undergo or initiate the same process.* Any special case, any supply of additional information calls for a different, sometimes laborious operation based on a re-sorting of the basic information.

However, with these conventional methods which are widely used by the Railway Administrations, it is possible to carry out, much more quickly and economically than by purely manual handling, many kinds of administrative work involving a great volume of data and a great number of parameters, such as the preparation of pay slips, the compilation of freight traffic accounts and statistics, supplies accounts, etc.

Moreover, as we shall see later, the existence of a punch-card system is generally prerequisite to the use of electronic data processing machines.

* * *

With the application of low-tension techniques (electronic valves) and semi-conductors (transistors), and with the advent of information storage facilities (« memories ») with immediate access (magnetic core systems) or high-speed access, i.e. after 1/50 000th of a second (magnetic tapes, drums and discs), it has become possible to dispense with all mechanical parts and thus to obtain operating speeds which are about a thousand times higher than those of conventional machines.

At the same time, owing to the use of binary numbers, where all the information required for a given operation can be expressed by a combination of « open » or « closed » positions of an electric circuit, it has become possible to take full advantage of purely electrical wiring schemes. Although the number of digits representing a given number is thereby increased to about three times the number of digits required in the decimal system, this drawback is greatly outweighed by the high speed of operation.

Moreover, and this is a vital characteristic of electric data processing machines, the use of the binary system permits to carry out *not only arithmetical operations but also logical operations.* As a result of theoretical studies, based on BOOLE'S algebra, it has been possible to interpret the process of logical reasoning as a series of binary schemes. To use a vivid phrase borrowed from a manufacturer : The association of the binary system and electronic circuits has permitted the construction of machines which *can size up the situation at the speed of light,* thus reproducing the action of the human brain. However, in spite of the journalistic use of such phrases as « electronic brains » or « robots », this does of course not mean that these machines can « think ». They are content to carry out, faithfully, and with « electronic » speed, the programs drawn up for them by men.

Here we must point out the second vital characteristic of electronic data processing machines, viz., the *recording of the working program in the machine itself,* and the automatic unfolding of this program as the data are received, associated with the storage of the results. Owing to the possibility of carrying out logical operations, it is possible to include in the program all the specific cases which are liable to occur, the « branching » to the corresponding subprograms being carried out automatically on the strength of comparative tests.

Thus, in contrast to punch-card machines whose working method is reminiscent of that employed by an industrial undertaking which uses conventional machine tools for mass production processes (where all workpieces undergo the same treatment at every stage of the work), the working method of electronic data processing machines is rather more akin to manual methods where each case is dealt with individually, with all its special features, before passing to the next case.

1.2. Brief description of an electronic data processing machine.

In principle, an electronic data processing machine consists of an assembly of units, each having a well-defined function, viz. :

— data and program input devices : with punch-cards, punch-tapes, and particularly magnetic tapes on which several millions of characters can be recorded;

— storage or memory devices, generally consisting of systems of magnetic cores or magnetic drums;
— an arithmetical and logical electronic computer;
— output devices, supplying results in the form of punch-cards, punch-tapes, magnetic tapes or printed statements.

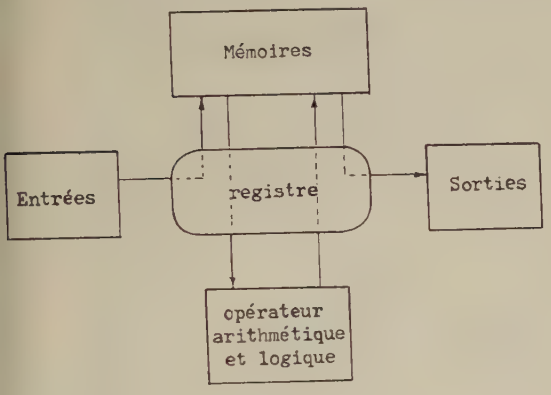


Fig. 1. — Theoretical arrangement of the different parts of an electronic data processing machine.

N. B. — Mémoires = storage. — Entrée = input. Registre = control. — Sorties = output. — Opérateur arithmétique et logique = arithmetical and logical section.

The general arrangement of the different parts can be represented in the form shown in figure 1.

This arrangement is absolutely general. The control unit represents an assembly of devices which permit the switching, at the right moment, of data coming from or destined for different units for the purpose of carrying out a program.

The actual layout of an electronic data processing machine, however, differs to some extent from this diagrammatic representation and corresponds to the arrangement shown in figure 2.

With the aid of the programs ([1]) and storage devices, it is possible to introduce all the variants of a problem and to reveal all the anomalies and special cases. As the number of units can be varied, it is possible to adapt the composition of the equipment to the specific needs of each user.

A major system may contain, in addition to the central computer and control unit :
— several magnetic drums;

([1]) Program : As already stated, the program is stored inside the machine. It consists of a series of instructions which are carried out one after the other in a given sequence.

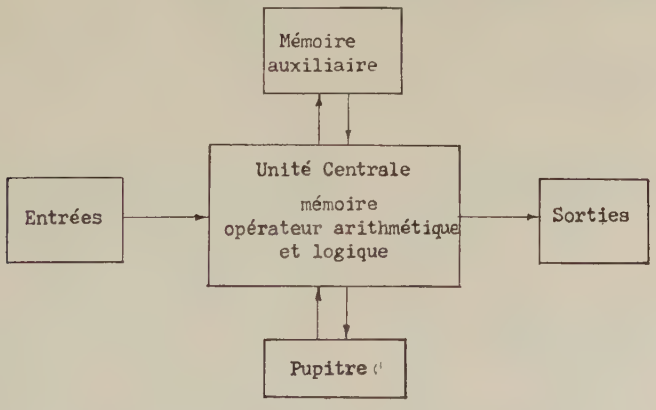
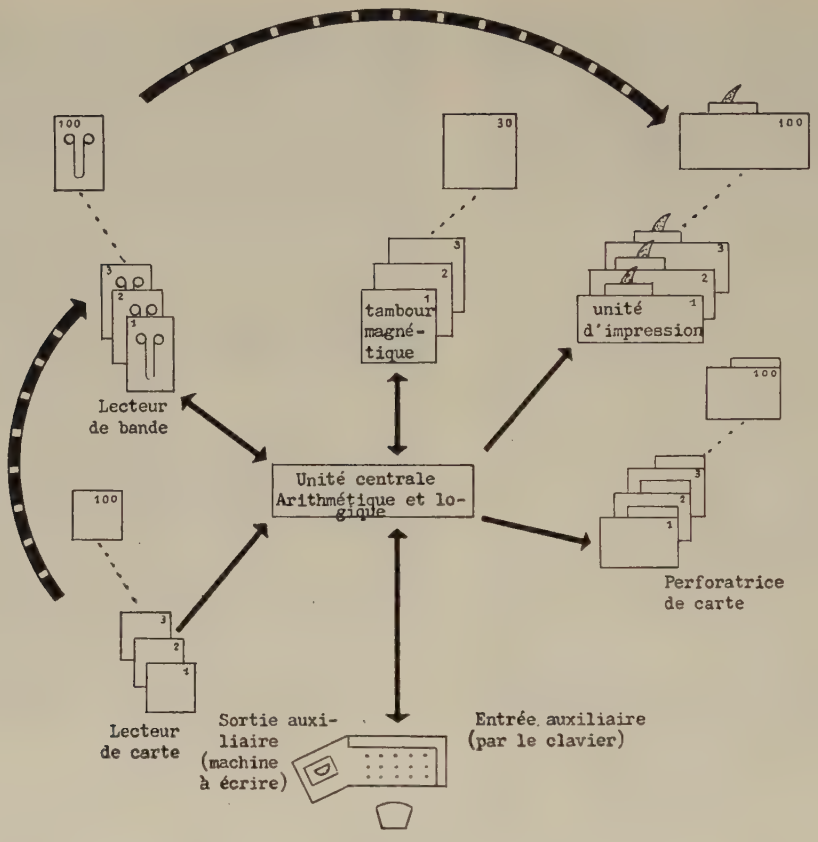


Fig. 2. — Arrangement of the different parts of an electronic data processing machine in practice.

N. B. — Mémoire auxiliaire = auxiliary memory. — Entrées = input. — Unité centrale = central processing unit. — Mémoire = memory. — Opérateur arithmétique et logique = arithmetical and logical section. — Sorties = output. — Pupitre = desk.



Connexion et sens de circulation des informations en opérations principales.

Connexion et sens de circulation des informations en opérations auxiliaires (opérations les plus couramment utilisées).

Fig. 3. — General layout diagram of the different parts of an electronic data processing machine.

N. B. — Lecteur de bande = tape reader. — Tambour magnétique = magnetic drum. — Unité d'impression = printing unit. — Unité centrale = central processing unit. — Arithmétique et logique = arithmetical and logical. — Perforatrice de carte = card punch. — Lecteur de carte = card reader. — Sortie auxiliaire (machine à écrire) = auxiliary output (typewriter). — Entrée auxiliaire (par le clavier) = auxiliary input (by keyboard). — Connexion et sens de circulation des informations en opérations principales = flow of data for main operation. — Connexion et sens de circulation des informations en opérations auxiliaires (opérations les plus couramment utilisées) = flow of data for auxiliary operation (operations most frequently used).

— between 10 and 20 reels of magnetic tape;
— a variable number of electro-mechanical printers, governed by the required rate of output of certain returns or statements such as pay advice slips, for example;
— two or three punch-card or punch-tape reading units;
— two or three units for the punching of summary cards or tapes.

In normal operation, all the data must pass through the central processing unit which is the working unit and the only one connected to all the others. It is, however, possible to transform the input data and output data without using the central processing unit by resorting to *auxiliary operations.*

The general arrangement of the different types of units used in an electronic data processing machine is shown in figure 3 which also shows, schematically, the different connections possible.

1.3. Development of electronic data processing machines: from scientific computers to management control.

As already mentioned at the outset, the appearance of the first « electronic data processing machines » only dates back to 1951. But it had been preceded, about a decade earlier, by the advent of « electronic computers », based on the same principles. Whilst the latter require only fairly limited data input and output devices for a very high computing capacity, the data processing machines do, in contrast, require input and output devices of a very high capacity; their development has taken much longer as it involved electromechanical, and no longer electronic techniques. On the other hand, the data processing machines are usually content with simplified computer devices.

Apart from this change of emphasis which has given rise to electronic data processing machines of high capacity, attention must also be drawn to a progressive evolution of conventional punch-card equipment which has resulted from a constantly spreading application of electronics in the constant search for further improvements in terms of speed and output. This evolution has affected first the multipliers and then the calculators. The flexibility of the latter was increased with the advent of program machines. Moreover, in order to increase their potentialities, especially in respect of capacity, the electronic calculators were connected to tabulators and thus formed the first interconnected « tabulator — calculator — summary card punch » system.

Also, the possibilities of programming increased considerably when it became possible to record the instructions not only on a plugboard but also on program cards read by tabulators.

Finally, with a view to improving the data input facilities, dual-feed tabulators have recently appeared on the market.

This evolution has led to the development of electronic data processing machines of medium capacity.

By way of example, this development is illustrated in *Appendix I* as far as the machines of the International Business Machines Corporation (I.B.M.) and those of the BULL Machines Company are concerned.

1.4. Brief technology of the components of an electronic data processing machine.

Some particulars about the development of the different organs are recalled below :

1.4.1. *Input devices.*

These are being perfected in various respects :

a) increase in speed of operation : the speed at which punched tapes can be read, for example, has increased, in a few years, from 450 to 12 000 characters a minute;
b) increase in the number of data input points. The latest electronic data processing machines are able to accept, simultaneously, data fed from several dozens of different input organs;

c) introduction of new techniques which permit direct electronic reading of data by brushing magnetisable points arranged during printing, and the automatic punching of cards at a speed of 500 per minute, or the direct reading of characters printed with magnetisable ink at a speed of 500 to 1 600 characters per second or, finally, the direct reading of figures with the aid of photo-electric devices at a speed of 500 lines a minute.

The data input devices most frequently used are thus still the punch-card and the perforated tape.

The cards are usually produced in premises close to the electronic data processing machines. There is, however, a tendency to decentralize punching operations. In this case, the cards are either forwarded by mail or reproduced on the spot, using hertzian or telegraphic channels.

The perforated tapes are produced either by teleprinter or by simple calculating machines or typewriters. *The choice of the number of channels entails no longer any problems :* All the card punching and tape reading devices can accept punched tapes with 5, 6 or 8 channels, regardless of the code used, and a device is available which permits the telegraphic transmission of codes other than the 5-channel codes which are at present most widely used.

1.4.2. *Output devices.*

Since the speed of conventional rod and wheel type printing methods appears to have a practical limit of 150 lines a minute, other techniques have been resorted to, such as :

— « flying wheel » printers, able to print 300 to 400 lines a minute;

— drum or wire type printers, able to attain speeds of 500 to 600 lines a minute;

— cinematographic reproduction devices which permit the recording of 2 000 characters a second on standard 35 mm film.

The following possibilities are also being studied :

— cathode ray tubes which permit either a momentary record of characters at a speed of 100 000 characters a second, or a permanent record at a speed of 25 000 characters a second;

— electromagnetic or electrostatic recording devices which can transcribe and retain data received from the cathode ray tubes, and which can operate at speeds varying between 4 000 and 10 000 characters a second.

1.4.3. *Storage devices.*

The following devices are mainly used, arranged in the order of increasing mean access times :

— magnetic core systems;
— magnetic drums;
— magnetic discs;
— magnetic tapes.

As far as *magnetic tapes* are concerned, these are now generally made of plastics, able to run in either direction, and provided with automatic recording control.

1.4.4. *Central processing units.*

The following two trends stand out clearly :

— use of transistors : with the general introduction of transistors, it will be possible to reduce the size and energy consumption of the central processing units and, at the same time, to simplify the air conditioning installations and maintenance service;

— developments of printed circuits which permit a considerable reduction of wiring and facilitate the replacement of elements.

In conclusion, the technical trend is towards electronic data processing machines of constantly increasing flexibility which are able to adapt themselves to the specific requirements of different undertakings. Also, owing to this flexibility as well as owing to the total inter-connection of the different elements, it becomes easier to adapt the equipment to the development of input and output techniques.

1.5. Programming methods.

The manufacturers are anxious to facilitate programming so that electronic data processing machines may be operated by staff with only a minimum of specialist training. For this purpose, they are developing techniques for automatic programming. The systems most widely used are the different « Compilers » produced by Remington-Rand, and the « FORTRAN » produced by I.B.M. The last-named system, originally conceived for the applications of scientific computing, should soon be fully adapted to management control problems. The manufacturers supply to their clients whole « libraries » of programs and subprograms.

1.6. Physical installations.

The installation of an electronic data processing machine calls for special measures, having regard to certain conditions not encountered with standard punch-card equipment. In particular, the air must be filtered, and air-conditioning must be applied to the premises in which the equipment proper, the magnetic tape magazines, and the maintenance team are accommodated. The temperature and air humidity fluctuations must not be allowed to exceed certain narrow limits, if reliable operation is to be ensured.

By way of example, *Appendix II* shows the layout plan for an I.B.M. Type 705 Computer. The floor space occupied by the equipment proper amounts to about 350 sq. m. The inclined ramps are needed to permit the provision of an installation floor where the electric feeder circuits and certain air conditioning ducts are installed. They permit the removal of peripheral units for maintenance purposes. The tapes are kept in a magazine, immediately adjacent to the entrance.

1.7. Operation and maintenance.

Electronic data processing machines can normally operate up to about 20 hours a day, five days per week. Because of the absence of mechanical parts, the central processing units merely require periodical adjustment tests. As far as the input and output devices are concerned, which contain mechanical parts, there are always several of them available which can be pooled so that these devices can be given a normal maintenance service, without interrupting the operation of the equipment as a whole.

With single-shift operation, one must reckon, on an average, with one hour of testing before work can begin. With double-shift operation, a second similar testing period is required. The few remaining hours are, in theory, wholly available for a third shift. In practice, as already mentioned, the maximum utilization per day is about 20 hours. In case of need, it is possible to obtain 25 to 30 hours of uninterrupted operation. In all cases, the manufacturers also require a continuous period of eight hours per week, generally on Saturday or Sunday, for maintenance work.

The number of operating personnel, supplied by the user, is extremely small. The normal team comprises a principal operator who supervises the progress of the program from his control desk and keeps the log book, and two or three operators who are responsible for the handling of the magnetic tapes. There are, in addition, a few operators whose number varies with the capacity of the input and output organs.

These figures are confirmed by the experience of American users, already extending over several years. Electronic data processing machines are remarkably reliable in operation. Involuntary stops do not exceed 3 to 4 % of the guaranteed working time, and are, in 75 % of all cases, due to failures in the input or output devices so that the repercussions are limited.

1.8. Principal machines at present in use.

It is difficult to compile a complete inventory. We shall confine ourselves to mentioning the best-known types of equipment without giving details of their par-

ticular features. In fact, a comparison of the basic features of each type of machine cannot, in itself, furnish valid information about their suitability or otherwise for dealing with a problem or group of problems, and the definition of a standard equipment is not possible because of the very great variety of combinations of operating units.

UNITED STATES :

BURROUGHS : DATATRON.
I.B.M. : COMPUTERS 305, 650, 705, 709.
LOGISTIC RESEARCH : ALWAC 800.
NATIONAL CASH REGISTER : NATIONAL 304.
RADIO CORPORATION OF AMERICA : BIZMAC.
REMINGTON RAND : FILE COMPUTER, UNIVAC FACTRONIC II, LARC.

EUROPE.

Western Germany :

I.B.M. : COMPUTER 650.

France :

BULL : GAMMA 60.
I.B.M. : COMPUTER 650 and 705.
SOCIETE D'ELECTRONIQUE ET D'AUTOMATION : CAB 2 000, 3 000.

Great Britain :

BRITISH TABULATING MACHINES : CALCULATOR 550.
ELLIOTT BROS. : ELLIOTT 405.
FERRANTI : PEGASUS AND MERCURY.

Sweden :

LOGISTIC RESEARCH : ALWAC 800 (under construction).

1.9. Approximate cost of electronic data processing machines.

As a general rule, the user has the choice of three alternatives :

— simple hire;
— hire-purchase;
— purchase.

To provide an indication of the order of magnitude, the monthly hire of an electronic data processing machine of medium capacity amounts to at least 5 000 to 6 000 U.S. Dollars whilst the purchase price varies between 200 000 and 300 000 U.S. Dollars.

For an electronic data processing machine of large capacity, the monthly hiring charge amounts to between 50 000 and 60 000 Dollars, and the purchase price may exceed 1 million Dollars.

* * *

CHAPTER II.

APPLICATIONS OF ELECTRONIC DATA PROCESSING MACHINES.

2.1. Information supplied by the Administrations.

2.1.1. *Germany (Deutsche Bundesbahn) :* The applications envisaged in the first instance would concern freight traffic accounts and statistics, stores control, and certain problems of statistics and planning.

2.1.2. *Austria (Oesterreichische Bundesbahnen) :* The Austrian Federal Railways intend to assign to one electronic data processing machine all the works at present carried out by conventional punch-card equipment, viz. :

— payrolls and pensions (number of staff : 90 000);
— premiums and control of train crews (number of staff : 7 000);
— staff accident statistics;
— control and statistics of freight traffic (550 000 consignments per month);
— control of receipts from international traffic (76 000 consignments per month);
— motive power performance statistics;
— supplies control (90 000 items and 200 000 stock movements per month).

The type of electronic data processing machine to be acquired will be so chosen that all the works listed above will only occupy about 60 % of its time in single-shift operation, in order to provide reserve capacity for future additional applications.

2.1.3. *Belgium (S.N.C.B.) :* The feasibility of the handling of payrolls (for a staff

numbering 70 000) by electronic data processing machines is at present being studied by several firms in collaboration with a committee consisting of four S.N.C.B. delegates. Descriptions of other works which are at present being handled by mechanical methods have been supplied to the firms which have been invited to submit proposals with a view to installing an electronic data processing machine of high capacity.

2.1.4. *Belgian Congo (OTRACO):* The following works will be assigned to an electronic data processing machine of an unspecified type :

— payrolls and control of staff (numbering 17 000);
— audit of receipts (350 000 cards per month);
— control of railway and river transports (100 000 cards per month);
— litigations concerning river transports (2 000 cards per month);
— sundry statistics (500 000 cards per month);
— supplies (35 000 items);
— planning of naval construction sites.

It is also envisaged to use the electronic data processing machine for operational research purposes (research on stock keeping problems, capacity of motive power units, correlation calculations, etc.).

2.1.5. *Spain (R.E.N.F.E.):* Investigations are being carried out with a view to using an electronic data processing machine for the movement control of goods wagons (numbering 80 000) in order to reduce the wagon turn-round time. It is envisaged, first of all, to reduce the time spent in marshalling yards, for the routeing of trains, and for loading and unloading. It is also envisaged to scrutinize the individual vehicle mileage statistics from a maintenance point of view.

2.1.6. *Finland:* The applications envisaged are :

— payrolls and control of staff (numbering 23 000);
— statistics and accounts of passenger and goods traffic (40 000 cards per month);
— supplies (1 500 movements per day), and finally;
— the movement of goods wagons.

It is intended to reserve a time margin of 15 % for exceptional work of a scientific character, especially for economic and commercial studies.

2.1.7. *France (S.N.C.F.):* The electronic data processing machines ordered by S.N.C.F. correspond to different conceptions of use.

2.1.7.1. The I.B.M. Type 650 Computer (without magnetic tapes) which is due to be delivered early in 1958, has been acquired in order to replace the conventional punch-card equipment which carries out, for the whole organisation of the S.N.C.F., the following operations on the strength of a single basic document, known as the « traction bulletin summary » :

— monthly calculation of the bonuses of drivers and firemen (numbering about 30 000);
— statistics of train mileages and trailing loads;
— statistics of fuels and lubricants consumed by motive power units.

In addition, the same equipment carries out numerous works on request. Altogether, some 18 million cards per annum are punched and processed.

The Type 650 Computer is intended to be used in two-shifts operation. The first shift will carry out the normal routine work in connection with the traction bulletin summary, whilst the second shift will deal with work of a non-routine character, particularly with scientific work which is developing rapidly. When the Gamma 60 plant described below has been taken in operation, the Type 650 Computer will, in principle, be used for the last-named type of work only.

2.1.7.2. The placing of an order for a high-capacity Bull Gamma 60 electronic data processing machine, due to be deli-

vered in 1960, conforms to a much more ambitious programme of centralizing the whole of the administrative, accountancy and financial work as well as certain aspects of the technical Administration of the S.N.C.F.

At present, important activities such as movement, supplies, parts of the accounts, etc., are still carried out manually whilst the control of staff, the payments to retired staff, accounts and control of freight traffic, supplies accounts and various statistics are carried out in 12 punch-card installations of the conventional type, all located in Paris and working either for the S.N.C.F. as a whole or for one of the Regions only. In all these cases, punch-cards are used exclusively, and all the cards (more than 200 millions per annum) are punched in the offices themselves. All the basic data are thus processed in Paris and the results are only available globally, after a certain time. Finally, all the offices work at present to the limit of their single-shift capacity, and a change-over to two-shift operation would cause difficult staffing problems.

An examination, carried out in 1956, of the possibilities offered by electronic data processing machines has resulted in a new conception of the organisation dealing with all administrative data. This conception is based on the following principles :

— mechanisation of all the spheres of administrative work;
— integrated processing of all the information contained in a basic document;
— decentralisation of the mechanical transcription of the basic documents;
— decentralisation of the evaluation of results or statistics of purely local interest;
— use of the so-called management by « exception method » where this method is able to improve management control.

This new organisation, which will in no way affect either the chain of command or the decentralisation of executive functions, will be based on the following apparatus :

— the Departments will continue to supply the basic data, either in the normal form of statements or, wherever this alternative seems to hold promise of improvement, directly in mechanically recorded form, e.g. in the form of perforated tapes;
— multi-purpose « District Centres », which will be provided with light mechanical processing equipment of the conventional type, will ensure the re-arrangement of the basic data within their own district; they will deal domestically with those data which permit the evaluation of statistics or results of local interest, and will forward their information to the central office;
— a central office, at headquarters, will ensure the centralized handling of all the data, and will produce all the statements necessary for the different managerial levels. It is this program which has prompted the placing of an order for the Bull Gamma 60 plant which is intended to work in two shifts very soon after being taken into use.

The S.N.C.F. emphasize that this operation must of necessity extend over a certain number of years. After this transition, the 12 existing punch-card installations will have disappeared.

A first-stage programme is envisaged and is at present the subject of definitive studies. It includes :

— payrolls and control of active staff (numbering 360 000);
— quarterly pensions for 400 000 retired members of the staff;
— social service payments (4 millions per annum, addressed to 1.7 million claimants);
— accounts and statistics of wagon-load freight traffic (600 000 consignments, representing one million cards per month);
— evaluation of the traction bulletin summary (see 2.1.7.1 above).

These different works are at present almost wholly carried out by means of mechanical processing methods.

The relative size of the constituent organs

of the Gamma 60 equipment has been determined by the specifications indicated above, e.g. :

— the printing capacity is governed by the handling of the payrolls;
— the size of the magnetic drum stores is governed by the social service payments, etc.

The subsequent stages of the programme will concern the other sectors of accountancy, the control of supplies, rolling stock movements, and finally budget control and costing. These further applications call for major feasibility studies which are at present in progress.

The S.N.C.F. do not contemplate the creation of a special transmission system for information destined for the electronic data processing plant. The forwarding of punch-cards or perforated tapes by night train from the district centres to the Gamma 60 installation is deemed to be sufficiently rapid for all the applications envisaged. However, if the studies concerning the movement problems should lead to methods which would call for very rapid transmission of information, use would be made of the general teleprinter system which is at present being developed.

2.1.8. *France (R.A.T.P.) :* The installation of an I.B.M. Type 650 Computer, planned for 1958, is prompted by two considerations :

— the execution of a special job concerning the time-keeping and payrolls of staff;
— a general improvement over the efficiency of the existing mechanical recording office.

The selected application concerns a problem which it would have been too onerous to tackle with the old methods. Its purpose is :

— to analyse the time-keeping of 11 000 bus conductors and drivers, classified by depots and by reasons for absence from work;
— to compile daily and weekly statistics on these items;
— to calculate bonuses, penalties, overtime;
— to keep up-to-date the individual records of hours worked, compensating time, holidays, annual leave.

The basic data will be introduced by means of mark-sensing cards (approx. 16 000 per day).

The results will relate to daily, weekly or monthly periods as required.

Moreover, the computer will gradually take over a certain number of jobs at present carried out by conventional equipment.

2.1.9. *Italy (State Railways) :* The use of a medium-capacity electronic data processing machine is envisaged for :

— payrolls and control of staff (numbering 160 000);
— control and statistics of freight traffic.

These works are at present carried out by means of specialized punch-card installations.

2.1.10. *Netherlands :* It is envisaged to use electronic data processing machines partly for known problems (such as payrolls), partly for problems difficult to tackle by conventional methods (calculation of wagon-load charges).

The Netherlands Railways lay particular emphasis on the advantage of being able to use electronic data processing machines also for work of scientific character which they have already promoted with the aid of punch-card equipment. They mention in particular, the following possible applications of electronic data processing machines:

— the solution of equations of a higher order;
— the calculation of timetables;
— the calculation of curve realignments.

2.1.11. *Poland :* Electronic data processing machines would be particularly useful in the following spheres :

— traffic statistics;
— supplies;
— marshalling of goods trains.

They would also be used for work of scientific character for which the Railway Research Institute is responsible.

2.1.12. *Switzerland (Swiss Federal Railways) :* The following applications are being studied :

— payrolls and control of active staff (40 000) and retired staff (25 000);
— inland wagon-loads traffic (150 000 consignments, including those which require clearance with the private companies);
— supplies (85 000 items);
— wagon movements (25 000 wagons).

It is also intended to study, at a later stage, the following applications :

— passenger traffic;
— general accounts;
— costing.

2.1.13. *Synthesis of the preceding information :* From the information supplied by those Administrations whose replies have been summarized above, it is possible to deduce very clearly certain criteria for the application of an electronic data processing machine.

2.1.13.1. The applications generally named as being suitable for a first stage of the use of electronic data processing machines are these :

— payrolls and control (in the widest sense) of active and retired staff;
— accounts and statistics of freight traffic;
— performance statistics (mileages and tonnages of trains, etc.).

The reasons for the prior choice of these applications are numerous : these works are, in nearly all cases, already carried out by punch-card methods which, though well developed, involve heavy work due to :

— the volume of units to be taken into account (which often exceeds 100 000);
— the great number of parameters (grades of pay, statistical classifications, etc.).

Electronic data processing machines are also expected to reduce the time within which the results become available so that decisions can be taken more effectively.

2.1.13.2. The following applications are also mentioned :

— control of supplies;
— control of rolling stock movements;
— general accountancy;
— costing.

Although it is not possible, on the strength of the replies furnished by the Administrations, to obtain a precise picture, it would seem that the problems concerned are mostly not at present tackled by comprehensive punch-card treatment, and that they represent applications where the use of electronic data processing equipment holds a promise of improved management control.

It is worth noting that the problem of distributing empty wagons has not been mentioned by any Administration. It is, however, a problem which it would be particularly interesting to study, in view of its repercussions on operation.

2.1.13.3. At least two Administrations have decided to use their electronic data processing machines as a means of centralized management. They propose to make a start with the applications already tackled by punch-card methods.

2.1.13.4. Most of the Administrations propose to reserve a part of the capacity of their electronic data processing machines for carrying out studies of a scientific character and, in particular, for operational research.

2.1.13.5. None of the Administrations mentions the use of special purpose electronic computers. In our questionnaire, we had referred, by way of example, to :

— seat reservation machines (studied by the airline companies);
— accounting machines (studied by the Post Office Money Order Departments).

2.1.13.6. The very great diversity of applications studied and, on the other hand, the profound differences as between one Administration and another provide ample confirmation that electronic data processing machines represent instruments of great flexibility of use, capable of making a worthwhile contribution to all management problems with which Railway Administrations are confronted.

In this connection, the order of magnitude of the volume of these works for which certain Administrations intend to use electronic data processing machines, does not appear to be different from that of the volume of work at present tackled by punch-card methods with other Administrations who have indicated to us that, in their opinion, the potentialities of an electronic data processing machine exceed their own requirements. Such a difference of opinion is, in our view, due to the fact that these machines are still very new.

* * *

2.2. Attempted outline of the principles governing the applications of electronic data processing machines.

On the basis of the replies received from the Administrations and the information gathered elsewhere, it is possible to draw up a list of the principal applications, starting with those which link up naturally with the routine methods of administrative management.

2.2.1. First of all, electronic data processing machines are able to carry out all those jobs which can be carried out with conventional punch-card methods, but with greatly improved speed and accuracy; their superiority is most marked where large-scale operations are involved.

2.2.2. Owing to the very principle of electronic data processing, it is possible to create, simultaneously, several specific index systems for the same category of data so that it becomes easier to keep up-to-date and to analyze the data pertaining to different parameters. The magnetic tape, in particular, affords a new solution to the problem of operating large-size index systems.

Moreover, it is possible to carry out spot checks while an operation is going on; the samples thus obtained can be recorded and kept up-to-date with a view to subsequent studies.

Finally, it is relevant to point out the ease with which it is possible to modify a given working program for the purpose of extracting information of an exceptional character. More often than not, such a modification will not even have any practical effect on the time required for the operation. With established punch-card methods, such a modification would call for a new processing of all the punched cards.

2.2.3. With electronic data processing machines, it also becomes possible to generalize the use of the so-called « exception method » or « variance method » for problems involving a considerable quantity of data and parameters. By way of illustration, we propose to describe further on how an electronic data processing machine is able to deal with a supplies problem.

On a series of magnetic tapes, a permanent stock ledger is recorded which comprises in particular, the identification number of each item, the consumption statistics for recent months, the orders placed, the re-order level adopted, the normal suppliers, etc.

Any changes in the level of stocks, any new orders, any modifications of the re-order level and any change in the list of suppliers, etc., are periodically introduced into the electronic data processing machine as and when the permanent ledger is processed. The program will prescribe that, as a general rule, the permanent ledger will simply be kept up-to-date, i.e. that a new series of magnetic tapes will be produced to replace the preceding series, without taking prints of the stock position. But the program will also lay down that, whenever a new movement causes the stock position of an item to become critical, judged by the application of the re-ordering level adopted (and this comparative operation will be made automatically for each item within a few micro-seconds), all the information concerning that item will be produced in print. The official responsible for watching the levels of stocks will thus be in possession of all the quantitative data which will enable him to decide the extent of the order to be placed, also keeping in mind such other criteria

as the plans for the coming year, the cash position, etc.

Thus, instead of having to consult periodically a considerable number of statements where most of the information is without immediate interest, the official concerned will be able to concentrate his attention on the comparatively few exceptions to the established rules, and to make correct decisions based on detailed and recent information.

This example shows clearly that decisions are not made by the electronic data processing machine itself. The machine merely provides the necessary data, and for this reason, an electronic data processing machine may be said to be an excellent tool of operational research.

2.2.4. By following up the same example, another application of electronic data processing machines becomes apparent. One of the documents indicating the movement of stocks and used for keeping the above-mentioned ledger up-to-date, is the « stores issue voucher ». As it happens, this document also contains data relevant to the accounts: price per unit, allocation to a given account, etc. With the aid of other programs, it will thus be possible to obtain, from the same document, the stocks accounts and certain data pertaining to cost accounts. It is thus possible, with the aid of the electronic data processing machine, to process the same document for several different purposes. This represents a considerable advantage compared with established punch-card methods where all the information contained in the basic documents must be processed successively, according to the nature of the results looked for. In practice, it is often necessary to punch several cards which must necessarily contain a considerable quantity of common identification data.

Generally speaking, the activities of any undertaking are reflected in a limited number of documents. An electronic data processing machine thus constitutes an instrument of centralized management. It can be regarded as an organ for simultaneous processing where all relevant data are concentrated and which is the distribution centre for all the results affecting the management of the undertaking. The equipment thus performs the function of a « management information centre », capable of supplying all the data for the calculation of cost prices and for the budgetary control. It is this conception which is reflected in the American expression « Integrated Data Processing ».

This is indeed the most characteristic contribution made by electronic data processing machines in the sphere of management control. It is hardly necessary to emphasize that, in an undertaking of such complexity as a railway system, such a conception can only be realized after prolonged studies, based on the analysis of the internal information channels, and that it must be supported by a suitable data transmission system.

It might be feared that such a concentration of management is incompatible with a decentralisation of executive functions. But this is by no means the case. On the contrary, owing to electronic data processing machines, the exercise of executive functions becomes more efficient at all levels, because precise and recent information required for taking decisions is made available. The introduction of electronic data processing machines as a means of centralized management is therefore not prejudicial to the preservation of the chain of command, although the possibility cannot be excluded that it may, in certain cases, bring to light the advantage of making changes in the existing organisation.

2.2.5. Finally, as already stated in Section 1.3, electronic data processing machines can be used for complex scientific calculations — a precious, if marginal, advantage of this technique.

2.2.6. It may be concluded, from this brief evaluation, that electronic data processing machines represent instruments of management of virtually universal use. They are in fact capable of finding solutions to all those problems where the data can be formulated quantitatively.

* * *

CHAPTER III.

ECONOMIC JUSTIFICATION FOR ELECTRONIC DATA PROCESSING MACHINES.

3.1. Information supplied by the Administrations.

The information supplied by the Administrations in this respect is rather sketchy, though it is possible to draw from it certain definite conclusions.

3.1.1. In the Belgian Congo (OTRACO), it is estimated that it will be possible to reduce the existing punch-card equipment by 75 %, with consequent savings in staff, which should cover the bulk of the hire cost of the proposed electronic data processing machine.

3.1.2. In Spain (R.E.N.F.E.), the savings effected by the introduction of the first stage of electronic data processing (control of freight wagon movements) are expected to be solely of an indirect nature, and not immediately quantifiable.

3.1.3. The Finnish Railways State, without providing quantitative information, that their economic assessment will merely take into account the savings resulting from the replacement of existing equipment by the electronic data processing machine.

3.1.4. In France, the Régie Autonome des Transports Parisiens state that during the first application envisaged (time-keeping analysis of 11 000 bus drivers and conductors; statistics and related matters; calculation of bonuses and keeping of staff records), the costs of working the I.B.M. 650 Computer will be about the same as the costs of the method at present in use.

3.1.5. The S.N.C.F. arrive at the same conclusion as regards the first applications of the I.B.M. 650 Computer (bonuses for train crews; tonnage, mileage and consumption statistics). As regards the Bull Gamma 60 equipment which is intended, during the second stage, gradually to take charge of all the management control problems, the studies have shown that the annual costs for the machinery of the new organisation (including those for the district centres whose function has been explained in Chapter II) will not be greater than the cost of the existing punch-card equipment, in spite of the fact that several new applications will be added. But the reductions in the establishment of punched card operators alone will ultimately result in a clear saving which will more than outweigh the cost of the machine, so that a substantial economic advantage is ensured. The calculations are based on an amortisation period of four years.

3.2. Outline of a procedure for assessing the economic justification of electronic data processing machines.

It would seem possible to evolve the following guiding principles :

3.2.1. If it is merely a case of transferring the work of an established punch-card equipment to an electronic data processing machine without change of methods, it is possible to carry out an ordinary economic comparison based on the cost of the equipment and that of the staff at present engaged in punch-card operations. This is mostly the case where the use of an electronic data processing machine of medium capacity is envisaged. The same method of calculation can also be used in the case of well defined manual works, carried out in specialized offices.

3.2.2. If it is intended to change the methods, a comparison becomes more difficult. The easiest way would seem to be first to carry out an economic comparison of the kind just described, and then to appraise the economic effect of the modification of the methods.

3.2.3. If it is intended to use an electronic data processing machine as an organ of centralized management — which may imply the setting up of a new organisation and will, in all cases, call for the introduc-

tion of the new system in several stages — the following method is suggested :

— determine the approximate composition of the electronic data processing machine (usually one of high capacity), which calls for a tentative estimate of the quantities of data to be handled and of the periodicities governing the handling of the principal problems;

— determine the intermediate stages which may be required, and the means of transmission to be set up;

— work out the total cost for the whole organisation, taking into account a period of amortisation not exceeding five years, in view of the fact that this type of machinery may become obsolete very rapidly;

— work out the direct savings ultimately to be expected (pre-existing machinery eliminated, and personnel and offices accustomed to the new organisation).

It will then be possible to work out, on the strength of the considerations listed above, the direct savings to be expected from the organisation of centralized management.

It will also be possible to estimate the order of magnitude of certain indirect savings, arising as a result of the anticipated improvements in management. For instance :

— reduction in the wagon round-trip time;
— reduction in the volume of stores, etc.

Savings of this kind will often turn out to be considerably more important than the direct savings.

If this first general study leads to positive results, the investigation will concentrate on the first stage of applications. It will then become possible to determine the precise composition of the equipment (assuming single-shift working in order to allow for subsequent extension of activities).

Finally, an estimate will be made of the time that should be reserved for scientific calculations.

3.2.4. In conclusion, it may be stated that :

— the direct savings can usually be determined fairly easily, whilst;
— the indirect savings (improvement in management control) can, at the outset, only be estimated approximately; but these may, in themselves, justify the decision.

There is, of course, a certain minimum volume of administrative work below which any kind of mechanisation ceases to be an economic proposition. The development of the conventional punch-card methods has shown that this minimum level is gradually lowered. It may be assumed that this will also be the case with electronic data processing machines if the following general considerations are taken into account :

— the volume of administrative work increases constantly;
— the cost of clerical labour also increases constantly;
— the cost of mechanized work shows a constant downward trend.

In consequence, and this is a well-known fact in the sphere of administrative organisation, those schemes for the mechanisation of labour which had shown doubtful economic prospects on first examination, should be periodically reviewed with due regard to the trends referred to above.

* * *

CHAPTER IV.

ORGANISATION OF STUDIES.

The organisation of the studies that must precede the installation of an electronic data processing machine constitutes a major problem, as has been stressed unanimously by the first users as well as by the manufacturers. As numerous Administrations are at present at that stage, we thought fit to devote a section of the questionnaire to these studies.

4.1. Information supplied by the Administration.

From the information supplied, a distinc-

tion can be made between three types of organisation :

4.1.1. Creation, at the highest level, of a special organisation entrusted with the duty to proceed with a preliminary study of a general character and, subsequently, to direct the detailed work. This principle has been adopted, in particular, in the Belgian Congo (OTRACO), in France (S.N.C.F.) and in the Netherlands.

In the Belgian Congo (OTRACO), the general policy is laid down by the central Administration. The studies are carried out by teams of two or three persons for each application, under the guidance of the Managing Committee. The members of these teams continue to attend to their normal duties.

In France (S.N.C.F.), a « Mechanisation Committee » has been called into being under the direction of the Deputy General Manager, and consisting of representatives of all the Directorates, Departments and Regions. This Committee has set up five working parties for the purpose of carrying out a preliminary analysis of the principal spheres of application which appeared to be possible :

— traffic;
— staff;
— accounts;
— stock control;
— commercial.

The working parties have been set up on a functional basis, i.e. they comprise, in each case, representatives of all those departments which take part in the circulation of the data concerned, from the preparation of the basic document to the evaluation of all the information extracted from it.

Parallel with these studies, the General Research Department at headquarters, which is responsible for punch-card methods, is carrying out a detailed technical study of the different machines in existence and has organized, with the aid of the manufacturers, information meetings for higher-ranking officials as well as detailed courses for the training of a number of specialists.

Once the decision had been taken, and the first applications had been determined, the definitive studies were centralized at headquarters. The part played by the research organisation set up for this purpose is confined to the definitive transposition and to the preparation of the programs for each application, in accordance with the methods prepared by the working parties and approved by the Directorates concerned. The organisation also prepares the physical installation and ensures, in conjunction with the manufacturers, the training of the necessary personnel. The organisation consists of a dozen young full-time officials.

The Netherlands Railways have created a body responsible for the general direction of the studies in which the following departments are represented : Operating, Traffic, Rolling Stock, Permanent Way, Signalling, Economic Efficiency, Finance.

4.1.2. A great number of Administrations take the line that electronic data processing machines represent the latest stage in the development of conventional mechanical methods, and have therefore entrusted the bodies responsible for these methods to carry out the investigations on electronic data processing.

This is the case in particular, in Germany (Deutsche Bundesbahn), Spain, Finland and Switzerland.

4.1.3. Finally, certain Administrations, such as Belgium (S.N.C.B.) and Italy (F.S.), have appointed full-time officials to study, with the specialists of one or several of the manufacturers, the use of an electronic data processing machine for certain applications.

* * *

4.2. Other items of information gathered by the reporter.

The general trend discernible from the information supplied by the Administrations is confirmed by information gathered from the manufacturers and various users of electronic data processing machines. In nearly all cases, the studies have been

initiated by a committee at headquarters level in which the heads of all departments are represented. After a preliminary exploration of the possible fields of application, and once the equipment has been chosen, the centralisation of the definitive studies is the procedure most frequently adopted. If there is a special department responsible for punch-card processing methods, it is usually this department which is entrusted with the studies: frequently, the work is attached to the Accountancy or Financial Department, which is the principal user of punch-card equipment.

With the first users, it has been common practice to call in consulting engineers, either for the selection of the equipment or for the direction of the studies. This applies, in particular, to undertakings which do not possess an Organisation and Methods Department of their own.

As regards the definitive studies, it is general practice to set up full-time working parties, specialized for each application. These working parties normally include specialists in administrative methods and programming as well as representatives of the departments concerned. These teams may comprise as many as ten persons.

Apart from these specialized teams, one often encounters other teams charged with the investigation of certain common problems such as codification, liaison, geographical divisions, etc.

It must again be stressed that it is absolutely necessary to study all the details of the information channels, especially where the conception of centralized management is practised. For example:

— the contexture of all the basic documents must be reexamined to ensure that these contain all the data required for simultaneous processing;
— the specialized codings, which may be of advantage in connection with the established punch-card methods, must be replaced by codings of general applicability;
— the methods of forwarding data and results must be studied in conjunction with the time lags deemed to be acceptable for each application.

The time taken up by these studies varies considerably. It can hardly be less than six months even in the case of a single transfer of mechanized work to an electronic data processing machine of medium capacity. In other cases, these studies will often take more than two years, even for the first group of applications.

* * *

4.3. Selection of equipment, and part played by the manufacturer.

The choice between different types of equipment must normally be made after the preliminary studies and economic calculations have been carried out. This choice is dependent on a detailed study of the different types of equipment and of the technical assistance available on the part of the manufacturers.

Once the equipment has been chosen, the part played by the manufacturer remains, in practice, a very important one in connection with the definitive studies. The manufacturer will normally place a team of specialists at the disposal of his client and will ensure the training of his programming and operating personnel.

It would, however, seem to be imprudent to entrust the whole of the studies to the manufacturer, or to a consulting engineer. The user alone is in a position to know all his requirements for information.

* * *

4.4. Study of the physical installation.

Especially with electronic data processing machines of high capacity, it is necessary to emphasize the importance of studying the physical details of the installation and the commencement of operation.

The study of the premises in which the electronic data processing machine is to be installed, together with such questions as power supply, air conditioning, etc., must be undertaken very soon after placing the order. It is, in fact, essential that all these installations should be ready before the electronic data processing machine is installed, and the supply of certain parts of the ancillary equipment may take just as

long as that of the machine itself (at present, generally some 18 months to two years).

The location of the installation is by no means immaterial. If an electronic data processing machine serving as a means of centralized management is usually installed at headquarters, it may be advantageous to install it in a separate building in conditions of greater calm, provided that suitable communications are available, e.g. by means of teleprinters.

Where, owing to the geographical structure of the Administration, it would take too long for the information originating from the different points of the system to reach headquarters, the electronic data processing machine might be installed at the « centre of gravity » of the system and connected with headquarters by means of teleprinters. Such an arrangement is frequently encountered in American undertakings.

If the structure of the Administration is decentralized and calls for the use of several electronic data processing machines, or if the machines are to be used in accordance with functional principles, their siting will normally be governed by the location of the headquarters of the departments for which they are destined.

Finally, it is necessary to study the operating problems well in advance : the cooperation of the operating staff, the organisation of the arrival and classification of data, the distribution and despatch of the results, the storage of the magnetic tapes containing the inventories (which may easily run into several thousands for an electronic data processing machine of high capacity), etc.

* * *

4.5. Recruitment and training of specialized staff.

It is unnecessary, for the investigation as well as for operation, to employ staff with specialized knowledge of the technology of electronic data processing machines. On the other hand :

— the staff entrusted with the preliminary studies must be well versed in the « internal logics » of the different machines that may be used;
— the staff entrusted with the definitive studies must have a perfect knowledge of the « program techniques » of the equipment chosen;
— the staff entrusted with the operation of the machine must have acquired mastery in handling the machine.

It follows that, particularly for electronic data processing machines of high capacity, the staff must be trained in several different ways.

This training can only be given by the manufacturers who organize courses for this purpose. Moreover, numerous Universities now include, in their lecture program, courses dealing with the principles and general applications of electronic data processing machines and scientific computers. These courses provide a useful introduction for the staff called upon to direct these studies.

Those Administrations which have already had to face this problem state that they have selected the personnel from among their own establishment, particularly among the punch-card specialists and among organisation and methods experts. As far as possible, they have looked for young people and, among them, for a certain number of university graduates. In a few cases, some recruitment from outside has been necessary.

In our opinion, although electronic data processing machines of medium capacity may be well served by staff having had a good training on conventional punch-card equipment, it would seem preferable to entrust the studies for electronic data processing machines of high capacity, destined for centralized management control, to staff not already « steeped » in established mechanical recording methods.

* * *

4.6. In conclusion, it must be emphasized that the importance, the complexity and the duration of the feasibility studies for an electronic data processing machine must not be underrated.

Faulty organisation, or inadequate co-

ordination of the studies, might result in considerable delays.

This is, as it were, the other side of the medal of the immense possibilities offered by electronic data processing machines and serves to emphasize the importance of endowing the leading officials with ample advance information.

* * *

CONCLUSIONS.

Although none of the Administrations who were consulted for the compilation of the present report have, as yet, had any possibility of acquiring practical experience with the use of electronic data processing machines, it would nevertheless seem possible to draw the following provisional conclusions :

(1) Electronic data processing machines are well suited to deal with the kind of problems encountered in railway management, and are able to bring about marked improvements, compared with the methods at present in use.

(2) It is inherent in the very principle of electronic data processing equipment that its composition can be adapted to the volume of work envisaged.

(3) Compared with conventional punch-card systems, the electronic data processing machines offer the following advantages :
— higher outputs and working speeds;
— application of the « management by exception » method;
— possibility of setting up a centralized management organisation;
— possibility of using the equipment for scientific calculations.

(4) The works that can most easily be carried out by electronic data processing machines and are therefore well suited as first-stage applications are those already dealt with by mechanical methods, particularly :
— payrolls and Administration of active and retired staff;
— traffic statistics and traffic audits;
— sundry statistics.

(5) The applications of electronic data processing machines in other spheres of management generally call for more detailed studies and, in some cases, for an intermediate stage of conventional punch-card recording. They include, in particular :
— the control of supplies;
— the control of the user of rolling stock;
— general accountancy;
— budgetary control;
— costing.

(6) The economic aspects of electronic data processing machines can be viewed from two different angles :
— direct savings, compared with present methods;

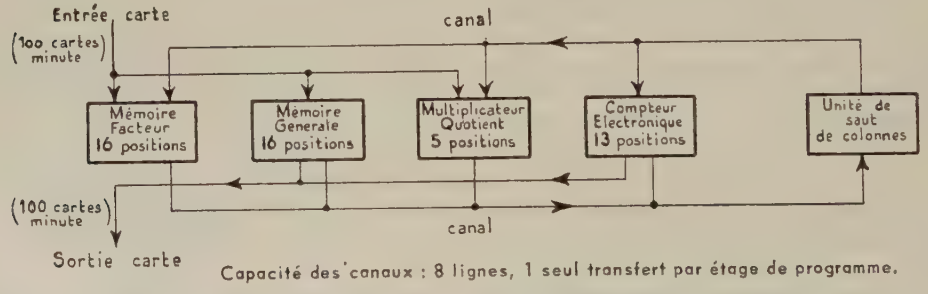


Fig. 4.

N. B. — Entrée carte (100 cartes minute) = card input (100 cards a minute). — Canal = channel. — Mémoire facteur, 16 positions = factor storage, 16 positions. — Mémoire générale, 16 positions = general storage, 16 positions. — Multiplicateur quotient, 5 positions = multiplying quotient, 5 positions. — Compteur électronique, 13 positions = Electronic meter, 13 positions. — unité de saut de colonnes = column skip unit. — Sortie carte (100 cartes minute) = card output (100 cards a minute). — Canal = channel. — Capacité des canaux : 8 lignes, 1 seul transfert par étage de programme = channel capacity : 8 lines, only 1 transfer per program step.

— indirect savings, resulting from a general improvement in the efficiency of management control.

The latter aspect, though more difficult to evaluate at the outset, is often predominant.

(7) The success of the introduction of electronic data processing machines depends, to a very large extent, on a sound organisation of the studies.

* * *

APPENDIX I.

Examples of the evolutionary chain leading up to electronic data processing machines.

I. — International Business Machines Corporation.

A. *Equipment of medium capacity.*

A-1 : *Type 604. Electronic Calculating Punch* (layout diagram, fig. 4).

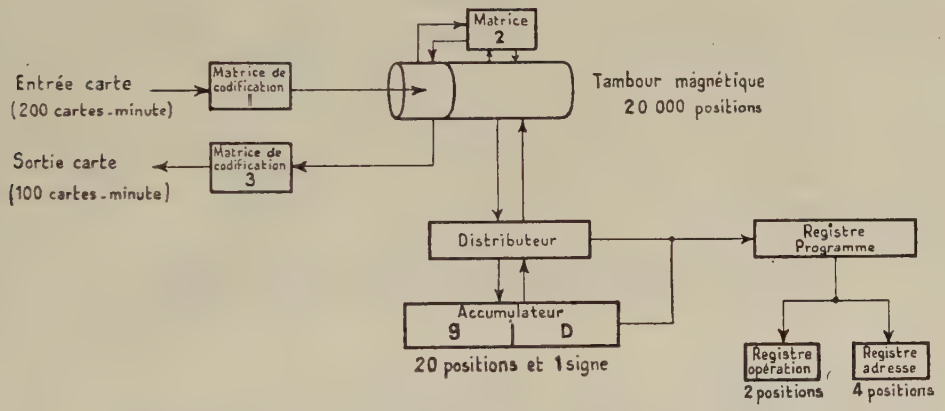


Fig. 5

N. B. — Entrée carte (200 cartes-minute) = card input (200 cards a minute). — Matrice de codification = code conversion. — Matrice = matrix. — Tambour magnétique, 20 000 positions = magnetic drum, 20 000 positions. — Sortie carte (100 cartes-minute) = card output (100 cards a minute). — Matrice de codification = code conversion. — Distributeur = distributor. — Registre programme = program register. — Accumulateur 9 - D = upper accumulator - lower accumulator. — 20 positions et 1 signe = 20 positions plus sign. — Registre opération, 2 positions = operation register, 2 positions. — Registre adresse, 4 positions = address register, 4 positions.

This diagram can also be shown in the following form :

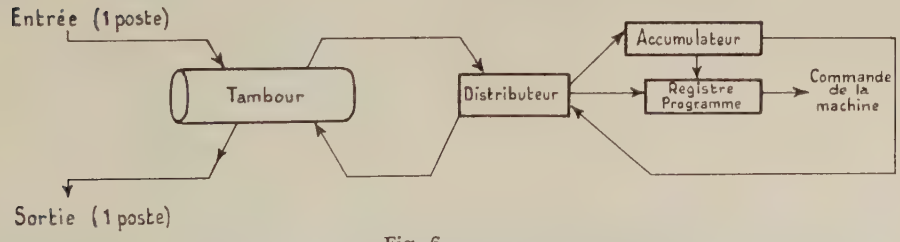


Fig. 6.

N. B. — Entrée (1 poste) = input (1 unit). — Tambour = drum. — Distributeur = distributor. — Accumulateur = accumulator. — Registre programme = program register. — Commande de la machine = machine control. — Sortie (1 poste) = output (1 unit).

A-2 : *Type 650. Computer* (layout diagram, figs. 5 and 6).

A-3 : *Type 650. Computer with magnetic tapes* (fig. 7).

B. *Equipment of high capacity.*

These machines have been developed from the first assemblies of scientific computers of Series 700. As already stated, this transformation has mainly affected the input and output devices whose potentialities have been increased with a view to tackling the specific features of administrative management control.

B-1 : *Type 705.*

This machine is grouped in a star-shaped layout around a central arithmetical and logical unit.

The first models had a central storage capacity of 20 000 positions

The following phase mainly consists in an increase in the number of input-output points.

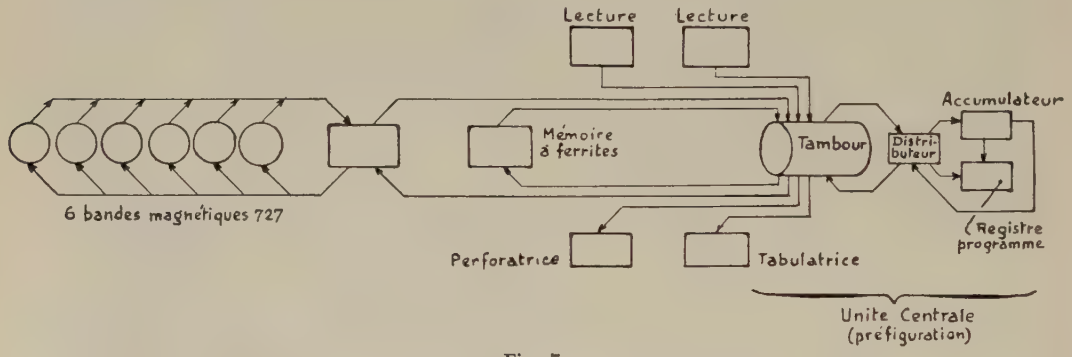


Fig. 7.

N. B. — Lecture = reader. — Mémoire à ferrites = ferrite coke memory. — Tambour = drum. — Distributeur = distributor. — Accumulateur = accumulator. — Registre programme = program register. — 6 bandes magnétiques 727 = 6 magnetic tapes 727. — Perforatrice = card punch. — Tabulatrice = tabulator. — Unité centrale (préfiguration) = central processing unit.

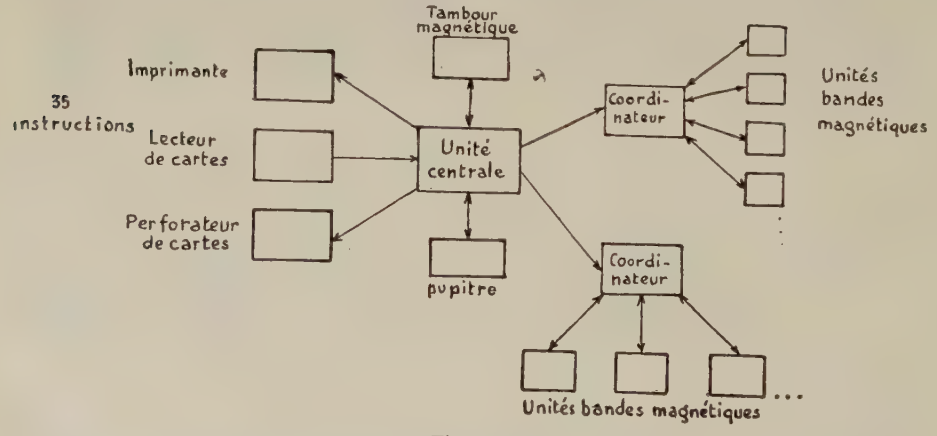


Fig. 8.

N. B. — Imprimante = printer. — Tambour magnétique = magnetic drum. — Coordinateur = control unit. — Unités bandes magnétiques = magnetic tape units. — Lecteur de cartes = card reader. — Unité centrale. — Central processing unit. — Perforateur de cartes = card punch. — Pupitre = desk. — Coordinateur = control unit. — Unités bandes magnétiques = magnetic tape units.

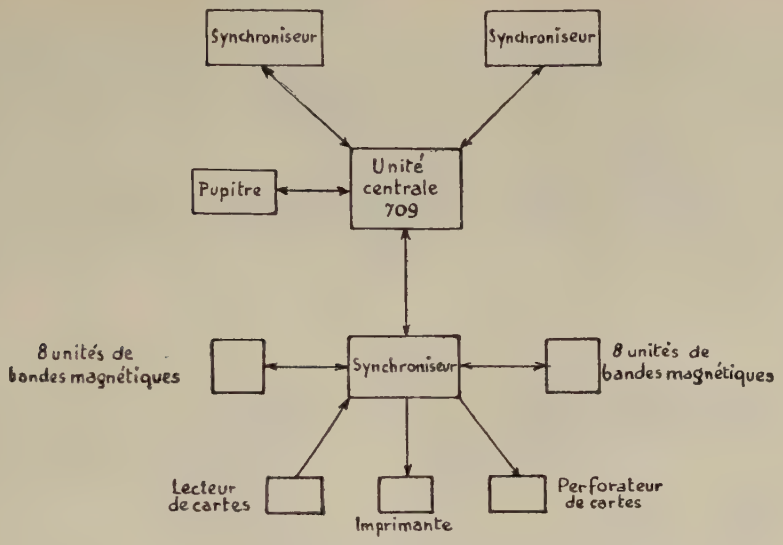


Fig. 9.

N. B. — Synchroniseur = synchronizer. — Pupitre = desk. — Unité centrale 709 = cenéral processing unit. — 8 unités de bandes magnétiques = 8 magnetic tape units. — Lecteur de cartes = card reader. — Imprimante = printer. — Perforateur de cartes = card punch.

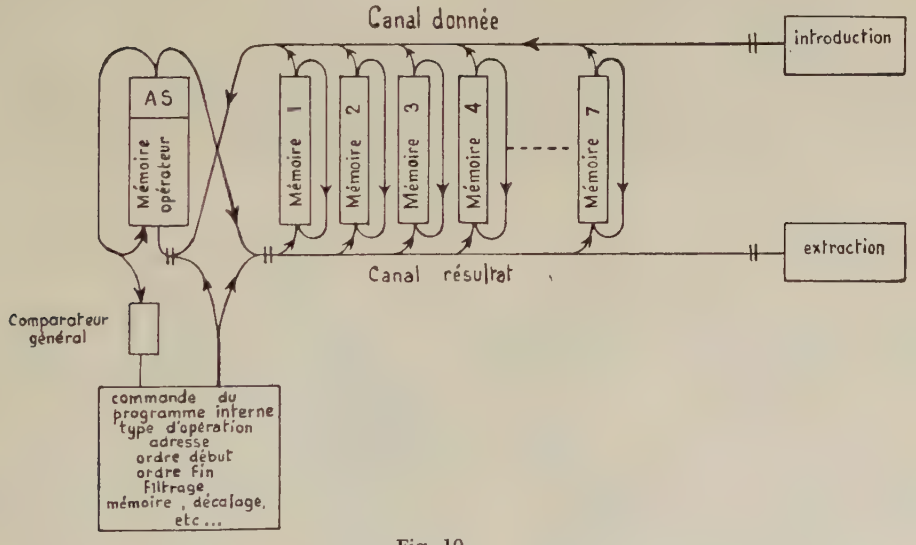


Fig. 10.

N. B. — Canal donnée = data channel. — Introduction = input. — Mémoire opérateur = operating memory. — Mémoire 1 = memory 1. — Mémoire 2 = memory 2. — Mémoire 3 = memory 3. — Mémoire 4 = memory 4. — Mémoire 7 = memory 7. — Canal résultat = results channel. — Extraction = output. — Comparateur général = general comparing unit. — Commande du programme interne, type d'opération, adresse, ordre début, ordre fin, filtrage, mémoire, décalage, etc. = control of internal program, type of function, address, starting instruction, stopping instruction, filtering, storage, unlocking, etc.

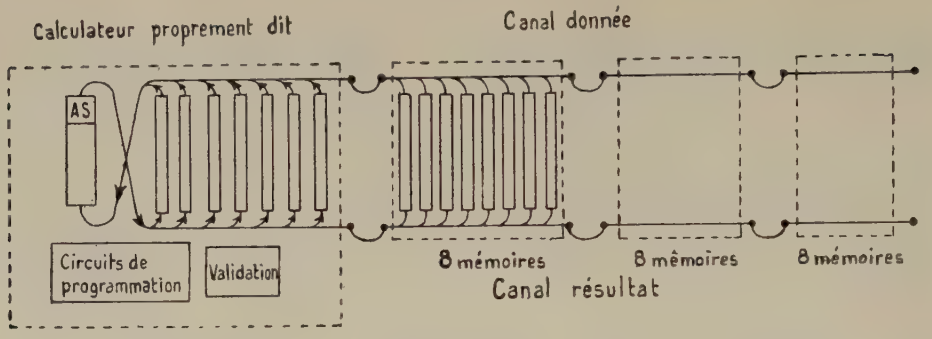


Fig. 11.

N. B. — Calculateur proprement dit = computer proper. — Canal donnée = data channel. — Circuits de programmation = programme circuits. — Validation = validity check. — 8 mémoires = 8 memories. — Canal résultat = results channel.

(like the drum of the Type 650 Computer).

The star-shaped layout :

(*a*) precludes simultaneous operation in the central unit, so that the machine can only work consecutively;

(*b*) requires the provision of an increasing number of control units destined to ensure the coding operations between units using different functional codes.

This limitation is partially mitigated by the tape control unit permitting the simultaneous operation of several magnetic tape units which have the function of buffer stores and thus increase, to some extent, the capacity of the central processing unit (fig. 8).

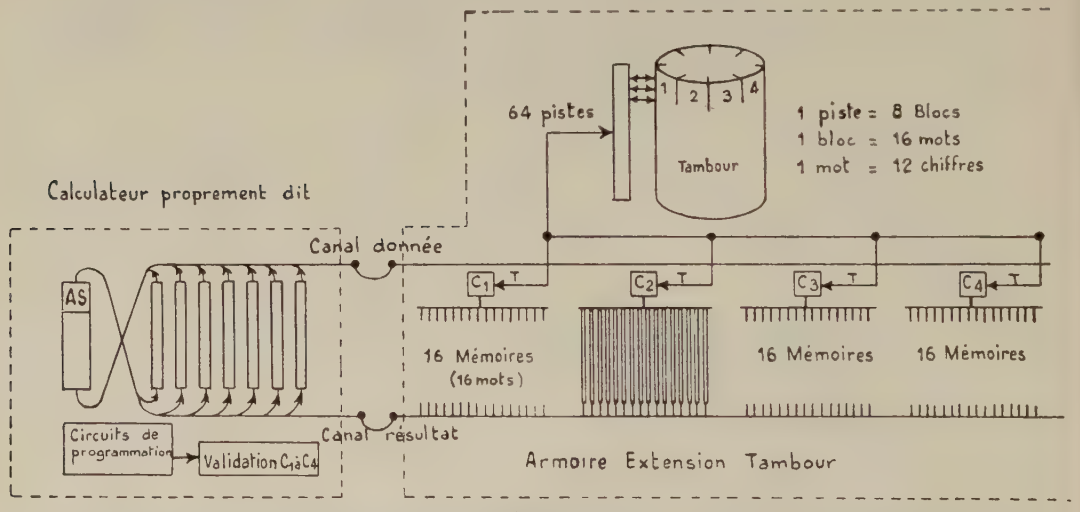


Fig. 12.

N. B. — Calculateur proprement dit = computer proper. — 64 pistes = 64 tracks. — Tambour = drum. — 1 piste : 8 blocs = 1 track : 8 blocks. — 1 bloc : 16 mots = 1 block : 16 words. — 1 mot : 12 chiffres = 1 word : 12 figures. — Canal donnée = data channel. — 16 mémoires (16 mots) = 16 mémories (16 words). — Circuit de programmation = programming circuits. — Validation C1 à C4 = validity check. — Canal résultat = results channel. — Armoire extension tambour AET = drum extension cabinet.

B-2 : *Type 709.*

In order to alleviate the difficulties outlined above, the Type 709 Computer offers :

(*a*) a very high capacity of the central processing unit, viz. 320 000 positions;

(*b*) the devices known as « synchronizers » which relieve the central processing unit of any input-output functions so that the synchronizers together with the input and output devices almost constitute « sub-Computers « of their own.

Moreover, with the possibility of carrying out the conversion of the different codes by means of programming, it has become possible to dispense with a great part of the control units used in the Type 705 Computer.

Working on the binary system, the machine is about ten times as fast as the 705, and is equally well suited for accountancy work and scientific calculations.

The layout diagram of the Type 709 Computer is shown in figure 9.

II. — Bull Company.

A. *Gamma 3 Standard Computer* (fig. 10).

B. *Gamma 3 Mathematical Computer* (fig. 11).

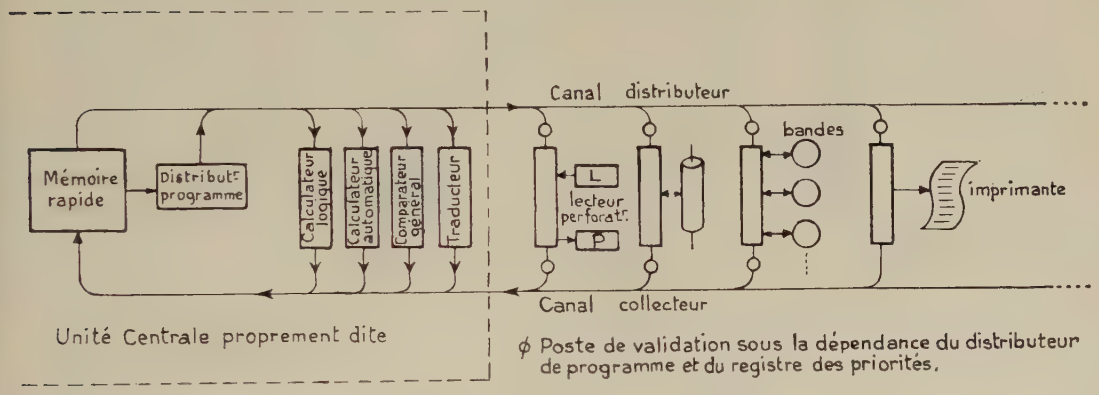


Fig. 13.

N. B. — Canal distributeur = distributing channel. — Mémoire rapide = high-speed memory. — Distributeur programme = program distributor. — Calculateur logique = logical computer. — Calculateur automatique = automatic computer. — Comparateur général = general comparing unit. — Traducteur = conversion unit. — Lecteur perforateur = reader punch. — Bandes = tapes. — Imprimante = printer. — Canal collecteur = collecting channel. — Unité centrale proprement dite = central unit proper. — Poste de validation sous la dépendance du distributeur de programme et du registre des priorités = validity check under the control of the program distributor and priority register.

The improvement consists essentially in an extension of the channels for data and results, which are connected to three supplementary blocks of eight storage units. Data reading and storing of results is done by means of punch-cards.

C. *Gamma Computer with magnetic tape (A.E.T.).*

The input and output channels are connected with four blocks of 16 stores. By means of switches controlled from a control point in accordance with the program, these blocks can be connected either with the channels or with the drum (fig. 12).

D. *Gamma 60 Electronic Equipment.*

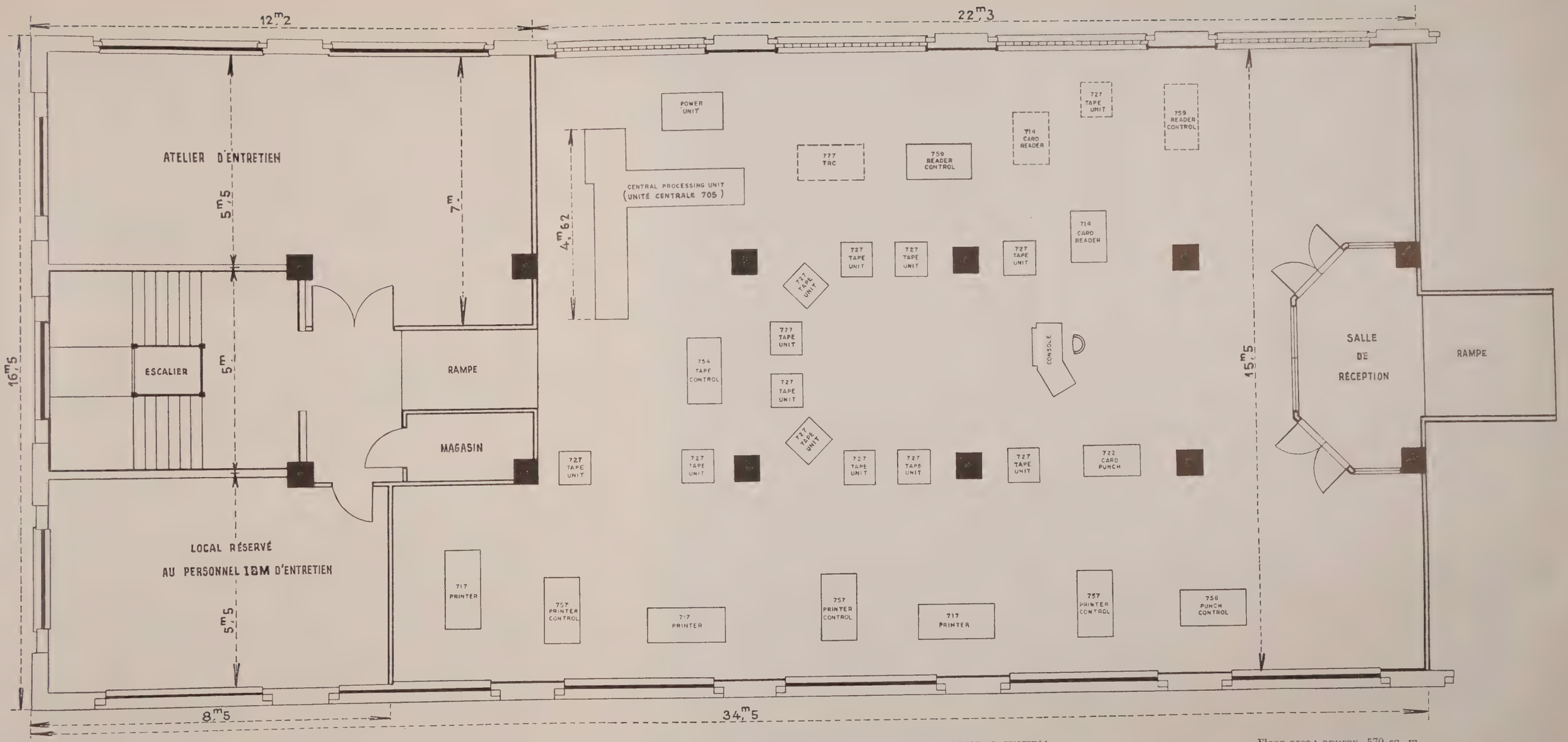
This equipment can be regarded as an extension of the gamma with magnetic tape where :

(1) the input and output channels are of such capacity that they permit the simultaneous passing of data of different kinds, coming from different units;

(2) the storage positions outside the central computer become liaison control units between the input-output devices and the validated data flows (fig. 13).

The liaison control units are provided with their own program concerning the functions which they have to fulfil.

* * *



LAYOUT PLAN OF AN I.B.M. TYPE 705 ELECTRONIC DATA PROCESSING SYSTEM.

Floor area : approx. 570 sq. m.

N. B. — Atelier d'entretien = maintenance shop. — Escalier = staircase. — Rampe = ramp. — Magasin = store. — Salle de réception = reception room. — Local réservé au personnel I.B.M. d'entretien = room reserved for I.B.M. maintenance staff.

INTERNATIONAL RAILWAY CONGRESS ASSOCIATION

17th. SESSION (MADRID, 1958).

QUESTION 8.

Financing and conserving railway properties and assets.

Study and comparison for limited companies, partially state-owned companies and State Railways, of the financial means used for the normal renewal of installations and rolling stock.

Forms of amortization and renewal, taking into account for the latter, the slow or speedy depreciation of the currency.

REPORT

(America (North and South), Australia (Commonwealth of), Austria, Burma, Ceylon, Egypt, India, Irak, Iran, Republic of Ireland, Japan, Malaysia, New Zealand, Norway, Pakistan, South Africa, Sudan, Sweden, Union of Soviet Socialist Republics, United Kingdom of Great Britain and Northern Ireland and dependent overseas territories),

by V. Felder, Dipl. Eng.,

Ministerialrat, Finanzieller Direktor der Österreichischen Bundesbahnen, Wien.

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VI. The present condition of the railway installations and intentions regarding their modernisation in the near future.

VII. Conclusions.

I. General.

The question included by the International Railway Congress Association in the agenda of the Madrid Congress is concerned with the financing of the invested capital of railways and the methods of conserving this capital. This question, which is of the greatest interest for any industrial undertaking, is of particular importance for Railway Administrations, for two reasons in particular. The first is that any mistaken decision in this field necessarily has the most unfortunate repercussions, because unlike other industrial and commercial undertakings, the railway has a great part of its capital invested in fixed assets. The second, due to the close interdependence in many countries

between the financial management of the railway and that of the State itself and to the adverse financial results, is the fact that the officials of the railway responsible run the risk of not always being able to supply in time the necessary means of conserving the substance of these investments. The critical situation which results becomes the more grave as the general political, economic, and social considerations of the State prevent the railways from obtaining receipts which will balance the cost of its commitments. Unfortunately, an insidious loss of its substance will not only have the effect of compromising its production capacity, but sooner or later will affect the safety of the traffic and thus the railway will lose its character of a safe economic instrument in the region it serves.

The questionnaire relating to question 8 was sent by the International Railway Congress Association to 35 Administrations (or Associations of Administrations) of the English speaking group. Of this number, 17 Administrations supplied the Reporter with a reply, 9 declared that they were unable to reply to the questionnaire, most often on account of reductions in staff, and no replies were received from the remaining 9.

The Reporter wishes to thank all those Administrations who sent him an answer. He is pleased to add that the length of some of the replies received shows the interest felt in the problem under discussion.

Although the object of his report cannot be to give in a synoptical form all the replies received to the different points of the questionnaire, which in fact often did not lend themselves to such a step, the Reporter will include in the following report many interesting particularities taken from these replies.

In the report, the names of the different Administrations have been replaced by the number given them in the following table :

Number.	Railways.
1.	Austrian Federal Railways.
2.	Egyptian Republic Railways.
3.	British Railways.
4.	London Transport Executive.
5.	East African Railways and Harbours.
6.	Malayan Railway.
7.	New Zealand Government Railways.
8.	South African Railways and Harbours.
9.	Ceylon Government Railways.
10.	Rhodesia Railways.
11.	Iranian State Railways.
12.	Coras Iompair Eireann.
13.	Japanese National Railways.
14.	Norwegian State Railways.
15.	Swedish State Railways.
16.	Nora-Bergslagen Railway for the Union of private Swedish Railways.
17.	Association of American Railroads.

II. The legal statutes of the Railway Administrations and the position they hold in the state.

Administrations mentioned under Nos. 1, 2, 5, 6, 7, 8, 9, 10, 11, 14, and 15 are State Railways, No. 16 and the railways grouped together under No. 17 are private Railway Companies, whilst Nos. 3, 4, 12 and 13 can be described as public transport undertakings.

In general, it can be stated that the structure of the railway undertakings of nearly every Continent has essentially the character of State Railways, whilst in the United States of America the railways are all private companies exclusively.

As far as State Railways are concerned, the funds needed for capital investments are provided by the State through its budget, or else they are authorised by the State to raise loans. In the first case, the State obtains the necessary funds either from its ordinary receipts, or also by raising loans, which are made either in the form of a special railway loan, or a general

State loan without special attribution of the amount raised.

In the case where funds are raised by loans, most of the State Railway Administrations are not generally responsible for the interest and sinking fund charges on the capital. Sometimes, however, the Railway Administration is responsible for the interest, but not the sinking fund charges. Only the Malayan Railway and the Ceylon Government Railways are responsible for both interest and sinking fund charges.

As regards the autonomy of the railway budget, this appears to be most endangered when the undertaking is a State railway. In the case of the Austrian Federal Railways, New Zealand Government Railways, Ceylon Government Railways and Norwegian Railways, the railway budget is part of the State budget. In the case of the Rhodesia Railways, this is only true of the investment budget, whereas the operating budget is drawn up independently of the State budget. On the East African Railways and Harbours, Malayan Railways, South African Railways and Harbours, Iranian State Railways, Japanese National Railways and Swedish State Railways, the railway budget is in fact autonomous, but it is subject to parliamentary authorisation like the State budget. Only the Egyptian Republic Railways, London Transport Executive, Coras Iompair Eireann, Nora-Bergslagen Railways and Association of American Railroads prepare their own budgets, quite independently of the State budget.

In this connection, it may be of interest to quote some extracts from the statements made by the Railway Administrations :

Austrian Federal Railways.

As regards the organisation, the General Management of the Austrian Federal Railways is incorporated with the Federal Ministry of Communications and Electricity, and as part of this Ministry, functions as the higher railway authority through the intermediary of specially appointed officials.

Capital is made available by the State to the Austrian Federal Railways by means of the national budget. The raising of loans, the conclusion of loan contracts, and other methods of obtaining credit are reserved to the State which in this connection acts in accordance with the authorisation to the extent allowed in the national budget.

Egyptian Republic Railways.

Since October 1956, the Egyptian Railways are an independent concern, having their own budget independent of that of the State. They are a public utility belonging to the Government and run by the Government. Their capital is completely State owned.

British Railways.

The British Railways belong to the « British Transport Commission » which is a public authority. The capital is supplied by the issue of British Transport Stock, the principal and interest on which is guaranteed by the Treasury.

The Commission's power to borrow for capital purpose is limited to the sum of £ 600 million, in addition to the compensation paid for the undertakings owned by the Commission by virtue of the Transport Law of 1947 or acquired by it.

According to the Transport Law of 1947, the Minister of Transport and Civil Aviation appoints the members of the British Transport Commission and London Transport Executive. The reorganisation and improvement programmes which involve considerable capital expenditure are drawn up by the British Transport Commission, according to directives which must receive the approval of the Minister.

East African Railways and Harbours.

The Railway Administration is a Corporation sole by name of the Commissioner

for Transport, dependent on the General Management of the High Commission, consisting of the Governors of Kenya, Uganda and Tanganyika, as well as the East African Central Legislative Assembly. The Commissioner for Transport is assisted by a Transport Advisory Council representing territorial interests.

The financing of capital investments is by means of public loans, guaranteed by the Governments of Kenya, Uganda and Tanganyika, as well as by contributions from the receipts through Betterment Funds.

Malayan Railway.

The Malayan Railway comes under the competency of the Minister of Transport and is run by a General Manager assisted by a Railway Board nominated by the Government and acting as a Advisory body. In certain special cases, amongst others, questions concerning the financial management, the General Manager is legally bound to apply to the Railway Board.

The railway budget, which is self-contained, is submitted for authorisation to the Federal Legislative Council.

New Zealand Government Railways.

The New Zealand Railway Administration is a Ministry of the State which is responsible for the operating under a Government Railways Act. The management is in the hands of the Minister of Railways. The funds for operating expenses, renewals and extensions are made available by the State budget adopted by Parliament.

South African Railways and Harbours.

A General Manager is responsible for the railways under the control of the Minister of State assisted by a Railway Board. Parliament has to authorise the railway budget, which is drawn up separately from the State budget.

The capital made available to the railway by the Treasury of the Union, which has not been paid back by the railways, comes from loans raised by the Treasury on the open market.

Ceylon Government Railway.

All the capital is supplied by the State and comes from loans at 3 ½ %; it is repaid to the State by the railway administration at intervals corresponding to the useful life of the installations acquired through these funds, classified according to the main groups of installations (in general 25 to 60 years).

Rhodesia Railways.

The Rhodesia Railways have come from the « Rhodesia Railways Ltd » taken over by the State in 1949. The Higher Authority as represented by the Minister of Communications and Constructions lays down the railway policy and nominates the members of the Administrative Council (Board of Directors) and the General Manager. The loan capital of the railway is obtained by the Federal Government of Rhodesia and Nyasaland.

With the approval of the Higher Authority, the Administrative Council can obtain funds by the issue of debentures or other suitable means, for certain purposes enumerated in the railways law, amongst others for the financing of investments representing an increase in assets.

The annual operating budget is submitted for the approval of the government, as well as the capital increase budget, which is drawn up for three years, and in future will be drawn up for 4 years.

Iranian State Railways.

The capital is entirely supplied by the Government. The influence of the

Government on the railway is regulated by law. The railway budget is prepared by the Administration, approved by a Supervisory Board (consisting of representatives of the Ministry of Roads and Communications, the Ministry of Finance and the State General Control Dept. of Accounts) and passed by the Council of Ministers.

Coras Iompair Eireann.

The Administration of the Irish Railways is a part of the organisation set up for the country as a whole to carry out transport by rail, road and canal. It is a public transport undertaking created by the State. Neither the latter, nor any other public authority share in the capital. The State, however, guarantees the interest and capital repayment in the case of funds borrowed by the Company in the form of « dated Transport Stocks ». It is not incorrect, therefore, to attribute to this undertaking to some extent the character of State railway, although it is not controlled by a Ministry.

The management and control of the Company are in the hands of a Management Committee nominated by the State.

Every year, the details of the operating account and capital account for renewals and new acquisitions are submitted for information to the State (Minister of Industry and Commerce).

Japanese National Railways.

The railways, which were operated by the State up to the end of 1949, have since then become a public corporation, the whole of the capital being supplied by the State. The Government or the Diet according to the law only intervenes in particularly important matters, such as the nomination or dismissal of Board members and decisions to be taken regarding the railway budget, which is submitted for approval to the Diet together with the Government budget.

Norwegian State Railways.

The Norwegian State Railways are an undertaking to be run according to generally accepted business rules. This undertaking is subject to government control, exercised by the Ministry of Transport; however the Administration considers that this control should be relaxed and it should be given a greater independence for its tariffs, decisions in connection with the operating, and as regards the staff.

The budget, which is drawn up by the company and checked by the Ministries of Transport and Finance, is presented to the Transport Commission of the National Assembly and passed by this Assembly on the recommendations of the Commission.

The capital required to construct new lines and to improve and restore existing lines is allocated each year to the State Railway Administration by the National Assembly from the public funds.

Swedish State Railways.

All the capital required is made available to the State Railway Administration by the Government. Decisions on railway legislation, passenger and goods tariffs, as well as the proposed annual budget, amongst other things, are the prerogative of the King through the Royal Council. The budget proposals are divided up into the general operating budget, the staff budget, and the capital investment budget.

Nora-Bergslagen Railway.

The « Nora Bergslags Järnvägs Aktiebolag » is a Joint Stock Company, in which neither the State nor any other public organisation have any part. The budget is drawn up independently, the State merely fixing the maximum tariffs for the transport of freight and passengers, and controlling the technical equipment.

Association of American Railroads.

In the United States, the State does not share in the capital of the private railway companies belonging to the Association of American Railroads.

Although the State exerts no direct influence upon the management of the railways belonging to the Association, it has an influence, through the intermediary of the Interstate Commerce Commission on the remuneration of service allowances and other questions in correlation with the railway operation.

III. The conservation of the substance of the capital invested and the accountancy methods used to represent this.

All the Administrations who replied were unanimously of the opinion that the conservation of the value of the assets should be assured by the operating or profit and loss account. Unfortunately, the questions asked concerning the amount of maintenance and repair costs, as well as the amount of the sinking fund costs and the real cost of renewing the installations, which would have given a clearer idea of the particularities on the different Administrations in this connection, were not fully answered by many of the railway Administrations. The information received by the Reporter is therefore insufficient to enable him to make any comparisons. Though this is unfortunate, it must be recognised on the other hand that a comparison of the absolute values, particularly in the field of finance and accountancy, is only of limited value, as even if the principles applied by the different Administrations were identical or similar, there would still remain numerous differences in the methods followed in practice and in the method of accountancy. The elimination of all such differences would have involved considerable preliminary research work which would have considerably exceeded the framework of our questionnaire. In any case, the replies received show that the expenditure in connection with the maintenance and renewal (amortization) of the railway installations in the case of the 6 Administrations, who supplied figures on this point, represent 35 to 50 % of the total operating costs, which clearly shows the considerable importance of the conservation of assets.

In this connection, the Reporter asks those Administrations who gave detailed information concerning the amount and distribution of the capital invested as well as of the costs and expenditure on conserving and renewing such investments, to excuse him for not being able to include all this data in the present report, for the reasons stated above.

Railway Administrations, like other industrial undertakings, have met the obligation to conserve the substance of their capital investments by replacing those which had become unsuitable for production by others. This material and technical necessity involves obtaining and using financial measures; this can be done in two different ways.

The oldest of the two methods, which has been given up long ago by industrial undertakings, is still used by many Railway Administrations, especially those having the character of a State railway on which there is a close interdependence between the railway budget and the State budget. This consists in including in the budget and the direct accounts the cost of renewal debited to the operating account. With this method, a reduction in value due to insufficient renewals, is not shown in the balance sheet.

The modern method, the result of economic reasoning, and probably used in industry generally, consists in debiting the operating account with the total of the sinking fund charges corresponding to the depreciation, and to put the opposite entry in the capital account, or, in the case of indirect depreciation, in a regulating

account. With this method, the cost of renewing and extending the installations comes into the capital account.

A similar effect is obtained by having a renewal fund which is allocated each year, according to the operating account products, sums corresponding to the depreciation of the installations. The actual cost of renewals are not credited to the capital account, but debited to the renewal fund.

Some Railway Administrations employ both methods, viz. debit the operating account with the actual cost of renewals for the installations as a whole, in particular to the infrastructure, permanent way, catenary, etc. and use the depreciation method for isolated installations dealt with individually.

There is no doubt that the depreciation method has the advantage of being more in conformity with modern industrial accountancy and of correctly keeping track of the capital, which is of considerable interest as regards the problem of the conservation of the assets, a matter of particular importance for railway undertakings in which the capital fixed investment is considerable. It must not be forgotten, however, that all methods of accountancy presuppose the existence of the financial means to acquire replacement installations.

If the receipts are insufficient to cover the cost of renewals debited to the operating account, and if no provision is made to meet an eventual deficit, for example in the general state budget, the first method will lead to cutting down on the renewal programme which is often unjustifiable economically and technically. On the other hand, the depreciation method does not in general allow of such an arbitrary cutting down of the operating costs and is more likely to lead to the consequences of the deficit thereby occurred being felt sooner.

The taking over of an operating deficit by the State is nearly always preceded by some cutting down, especially in the funds needed for renewals, which in the end may result in a dangerous position as regards capacity of production and safety of operation. The danger of such a loss of substance is not diminished by the fact that for a certain period it is barely visible below the surface as it were, and only perceptible to the expert responsible for the management. The situation, however, becomes absolutely insupportable when the Railway Administration has to bear burdens other than its own to the profit of other economic and administrative sections of the country, and is forbidden for reasons concerning the general political economy and the wages and prices policy to introduce profitable passenger and freight tariffs. It is one of the essential duties of statesmen and economists who are conscious of their responsibilities, to break — the sooner the better — this vicious circle and thus establish the preliminary conditions for a healthy financial and economic policy for the railways and a reasonable co-ordination of all the transport undertakings. In connection with this subject, we would refer to the fundamental and very promising works of the International Railway Union and the Conference of the European Ministers of Transport.

The repercussions of a reduction in purchasing power on renewals and depreciation will be dealt with in Chapter V.

The calculation of the depreciation sums is generally carried out on the linear method, taking as basis the initial purchase prices, and sometimes in the case of reduced purchasing power, the replacement costs, as well as the useful life of the different installations.

In the case of the few Administrations. who communicated the depreciation rates as a function of the useful life as used in their accounts and their calculations of costs, or as obtained from their other than accountancy studies of theoretical renewal requirements, divided up according to the groups of installations, we give below the limiting percentages used :

Group of installations	Amortization rate as % of capital investment.
Fixed installations :	
Bridges	0.7 to 2.5
Buildings (stations)	1.0 to 2.2
Tunnels	1.0 to 2.5
Water and coal supply installations	2.0 to 4.0
Permanent way superstructure	1.8 to 4.0
Safety installations	2.0 to 3.5
Telecommunication installations	2.0 to 3.5
Catenaries	1.5 to 2.5
Shop buildings	1.7 to 3.3
Other shop installations	4.0 to 10.0
Rolling stock :	
Steam locomotives	2.3 to 3.0
Electric locomotives	2.3 to 3.5
Diesel locomotives	3.3 to 5.0
Coaches	2.5 to 5.0
Wagons	2.2 to 4.0
Railcars	12.5 to 33.3
Lorries	10.0 to 33.3

Together with the financing of the renewals of railway installations, it was also asked what depreciation rates were applied by industrial undertakings in the country for industrial installations comparable with those of the railway and approved by the fiscal authorities. There were very few replies to this question, perhaps because most railway installations are special installations adapted to their purpose, so that it is hard to find anything similar in ordinary industrial undertakings. In general, however, it can be stated that there are no special differences between industrial and railway undertakings, although there is a tendency for shorter depreciation periods in industrial undertakings than in Railway Administrations.

This tendency may be due in part to the fact that the depreciation is only authorised fiscally for the nominal accountancy value; it will be wiped out in those countries where, on account of a great reduction in the purchasing power, a revaluation of the installations is allowed by law in the balance sheets, one single such revaluation being allowed. The need to catch up with the accumulated delays in renewals on several Administrations, and to follow technical progress, in the opinion of the reporter show that it is advisable to reduce rather than prolong the useful life on which the depreciation periods are based.

As regards the methods applied by the Railway Administrations and their special features, we give below a few extracts from the replies received :

Austrian Federal Railways.

The political events of 1938, the second world war from 1939 to 1945, and the ten years which followed, and the property rights both in the case of private and State property which were often badly settled until the drawing up of the Austrian treaty in 1955, prevented or at least

advised against any detailed research into the property of the Austrian Federal Railways. The management of these railways could not therefore be based upon a pertinent estimate of the capital invested, and the Administration was obliged to determine the value of renewals haphazardly from the 1937 balance sheet, using different evaluations and price indices. This work was rendered doubly difficult by the enormous destruction of precious documents during the end part of the war. The expenditure required for renewals intended to conserve railway property have to date been directly debited to the operating account, without, for the reasons given above, it being possible to supply any concrete proof from accountancy documents that the conservation of the assets was not being carried out as would have been wished and that delays in renewals were accumulating. At the present time, the relisting and re-evaluation of the installations is being carried out, and the Administration of the Federal Railways proposes to introduce accountancy methods based on the modern principles of industrial economy.

Egyptian Republic Railways.

The railway installations, which are considered to be the most important as regards conservation and renewal are the rolling stock and the superstructure of the permanent way. Too prolonged use of such installations may be the cause of accidents and this situation involves therefore high maintenance costs. The Egyptian Railways have drawn up a fixed renewal programme.

The systematic carrying out of this programme has been hindered to date by a shortage of material and industrial means, the absence of correctly calculated depreciation rates, as well as import difficulties during the two world wars and even long afterwards. As a result, there have been arrears in renewals, for the elimination of which special funds have had to be allocated from the State budget.

Before October 1956, the funds for carrying out the annual renewal programme were taken from the railway budget, which was then incorporated in the State budget, and were not financed by sinking funds.

In certain special cases, loans were made from Government pension and insurance funds or from the funds of the Ministry of Finance to cover operating deficits on the railway.

British Railways.

Whilst the accountancy value of the capital investment of the British Railways amounts to some £ 1 600 million, the renewal costs are estimated to be some £ 5 000 million.

The accumulated depreciation was evaluated for the last time on the 1st January 1948, taking into account the age of the installations, as well as a reserve for the technical ageing of much of them.

It was not possible to give a relative idea of the sum of the accumulated depreciation, taking into account the replacement value of the installations, viz. £ 5 000 million.

The credits from the residual values are credited to a special annual reserve fund.

Whilst the British Railways make use of the depreciation method, especially for the rolling stock and the railway plants and equipment, no amortization is allowed for the lands, buildings, permanent way and other constructions; the resulting loss in assets is compensated by the renewals carried out which are debited to the receipts account.

The Transport Act of 1947 laid down expressly that : « the British Transport Commission is bound to charge to Revenue every year proper provision for depreciation or renewal of the installations... ».

If the profit is sufficient to allow of a reserve fund to be set up, it is intended to set these funds aside for amortization

likewise, to cover the additional cost of replacing the installations.

London Transport Executive.

The London Transport Executive, which forms part of the British Transport Commission, is not a purely railway undertaking, as it also operates very considerable road services.

As regards the railway installations, the depreciation and renewal principles are identical with those reported above for the British Transport Commission.

East African Railways and Harbours.

The capital investments are shown amongst the assets in the case of the initial cost of acquisition. The sums allocated to renewal of the installations should cover the actual cost for the equivalent replacement of wasting assets. The net sums, which are not used and accumulated, are collected in the renewal fund shown on the balance sheet.

Whereas at the end of 1956, the actual expenditure on installations liable to wear amounted to some £ 64 million, the cost of replacing such installations was estimated to be about £ 141 million.

The renewal funds are checked every ten years, and also in the meantime should the market prices rise. If this investigation shows that the endowment from the receipts is insufficient, this is revised. The deficiency for the previous years is made up from special contributions, according to the financial possibilities, from a Net Revenue Appropriation Account.

It can be stated that the contributions from the renewal funds are determined according to the corresponding replacement costs, and the average agreed useful life. In this contribution of the renewal fund, no account is taken of the residual value (proceeds of sale) of replaced installations because, if necessary, such proceeds are credited to the net receipts. The contribution of the renewal fund is assured even if there is an operating deficit, this deficit being carried forward to succeeding years till it is wiped out.

Malayan Railway.

This Administration also includes the capital investment in the assets at the initial value. The actual cost of replacement would be nearly four times as great.

The annual allocation for the renewal funds is determined by the linear method, taking into account the estimated useful economic life and the cost of renewal. This renewal fund is used to finance equivalent replacements, whereas the plus-value factor of new capital investments is financed by the capital.

New Zealand Government Railways.

The investment capital is included amongst the assets as far as the initial first cost or purchase price is concerned. No revaluation owing to the devaluation of the currency has yet been made. It can be taken that the actual cost of replacement would be two to three times greater than the sum entered in the 1956 balance sheet.

In general, all the installations, with the exception of the permanent way superstructure, are the subject of depreciation. The expenditure required for renewing the permanent way is entered directly in the operating account. In addition, an equalization fund has been set up to supply the necessary funds during periods when particularly extensive renewals of the permanent way have to be carried out, thus avoiding considerable fluctuations in the annual operating accounts.

The New Zealand Government Railways appended to their replies to the questionnaire a historical report on the problem of depreciation and renewals, as well as the way this is dealt with in the accounts, extracts of which we give below on account of their interest :

« Before 1925, the Railway Administration had no proper financial system; all the receipts and expenditure were entered in the State account. No reserve funds of any kind were provided, and in general the important installations acquired were entered as operating expenditure. Installations that were abandoned and not replaced were not written off. Since 1925, separate railway accounts have been kept in the State accounts, but this solution has not been satisfactory if only on account of the different charges imposed. In 1931, a revision of the assets and liabilities was carried out, and the necessary sinking funds and reserve funds were given priority over the payment of interest to the State. »

The depreciation rates for the buildings and bridges are based on their useful life which is determined much more by natural conditions than wear and consumption in service. In the case of the rolling stock, both wear and consumption are taken into account, as well as ageing in order to determine the useful life.

The depreciations are calculated according to the revaluations of 1931, and in the case of installations acquired since that date, according to their purchase price or cost.

Whereas for most of the installations the straight line method of percentages calculated from the cost and useful life is applied, in the case of the shops, houses and buildings, in particular, the operating account is debited according to the method of the amortization table, taking the interest into account as well.

South African Railways and Harbours.

The replacement of installations susceptible to wear is financed by a renewal fund the object of which is to assure a uniform distribution of expenditure under this heading over the different years. Although in principle the sums inscribed in the depreciation funds should only be used for the replacement of existing installations, it is the practice, especially in the case of rolling stock and repair shop equipment, to use these funds also to buy additional equipment. The fund is fed by annual contributions from the receipts, taking into account the acquisition costs of the installations and their estimated useful life. Payments made from the funds are equivalent to the whole cost of renewal, when the new installations are of the same type and size as the old ones they are replacing, even if the new installations cost more than the old ones did.

In the case of non-equivalent replacements, with definite improvements over the old installations, the additional cost is debited to the capital account. As regards permanent way materials, the plus value is not calculated from the additional cost, but on the basis of the increase in weight of these materials.

This exceptional financing mentioned above of the additional installations from the endowment of the funds is explained by the fiction that such additional installations make up for the depreciation in the installations still in service, so that as a result the average age of the whole of the installations of this group remain unaltered.

When installations are removed or taken out of service in any way and are not replaced, the value of acquiring these installations is credited to the capital account by the transfer of the amount from the contributions used for this purpose from the renewal fund, and the difference is wiped out by debiting the operating account.

The contribution of the renewal funds is shown in the annual accounts, whether the results for the year show a profit or deficit.

Ceylon Government Railways.

The funds needed for replacing installations are made available by the State under the same conditions as those required for the initial purchase of such installations (cf. page 728/22). Normally, the loan

originally obtained for such purchases must be repaid when the estimated installation life has been reached.

Rhodesia Railways.

The capital invested shown in the assests on the balance sheet represents the real cost of manufacture or purchase at the time of such manufacture or purchase.

It was not possible to state what is the present renewal value of this installation compared with the value shown in the balance sheet.

The Rhodesian law on the railways stipulates that the sums given under the heading of railway receipts for each year should be used to cover the necessary expenditure on amongst others maintenance, renewal and depreciation, and in addition if during any year the railway receipts are insufficient to cover the above expenditure, the difference should be covered from funds from the stabilisation of prices and wages account. If the funds available in this fund are insufficient in their turn, to cover the whole of the difference, the Government will regulate the balance of this difference.

The amount of the Depreciation and Renewals Account represents the accumulated depreciations of the installations on basis of the estimated useful life. From 1957, it is proposed to divide this account up into a depreciation account for Unit-Assets and a renewal account for Group-Assets, such as the permanent way for example, to act — as a equalisation — account for the actual renewals of these Group-Assets.

To the first category (Unit-Assets) belong such things, for example, as the rolling stock, lorries, workshops and machine shop installations, buildings, etc.

Amongst the Group-Assets are amongts others the superstructure of the permanent way, tunnels, bridges, telecommunication installations, signalling installations, and the fences alongside the lines.

Whilst, consequently, there is no amortization of the value of groups of installations and the stability of their value is obtained from renewals carried out and debited to the operating account — if needs be through the intervention of a compensation account spreading the cost over several years — the annual sums to be allocated for the depreciation of isolated installations are checked and if necessary corrected every 5 years, to make sure the bases taken for the accounts agree with the economic evolution.

Iranian State Railways.

To finance the cost of renewals, the necessary amounts are provided for in the operating budget and reserved at the end of the year in the « Sinking Fund Reserve ». The Government meets any railway deficit from the general State receipts, if renewal costs cannot be met from the operating receipts. The endowments of this fund are considered to be obligatory.

Coras Iompair Eireann.

The value of the capital invested as shown in the balance sheet of the Irish railways does not correspond to the present cost of renewals. It represents the initial cost of acquisition, both in the case of the original installations and the replacement installations which took their place, less the depreciation. It was not possible to give any estimate of the difference between this accountancy value and the cost of renewal.

The depreciation provisions, which are considered binding, are not allowed to accumulate but are debited to the operating account and credited to the capital account. In the case of the running lines installations, the amount of depreciations is fixed according to the average annual cost of renewal at the present time.

There are special regulations concerning the steam locomotives, the accountancy value of which is amortized over ten years.

Actual renewals are carried out every year, more or less to the extent indicated in the estimates, so that there are only insignificant differences compared with the theoretical figures.

Japanese National Railways.

There is no agreement between the legal public undertaking which runs the Japanese railways and the State or other public bodies as regards renewals which cannot be met from operating receipts. In cases of this sort, the renewals are either put off till a later date or their cost is met by a loan. If such a situation continues, it will inevitably lead to an increase in the passenger and freight tariffs.

The considerable inflation from which Japan suffered after the second world war, and the stabilisation of the national economy since that date, have led to a new evaluation of the capital invested, dated the 1st April 1955. As will be seen further on, the purchasing power of the yen has fallen during the last few years to less than 3 $^{0}/_{00}$ of its 1935 value, which corresponds to an increase in costs since that date of about 370 times.

In 1955, at the same time as the cost of renewal was brought into the assets, the adjusted value determined as a function of this replacement cost and the proportion of the estimated useful life that had already passed by the linear method of amortization was debited.

Whilst for most of the installations, the depreciation method is used, the permanent way and catenary, for example, are included in particular in the balance sheet at their cost price (or renewal price) without any modification, and any replacement of such installations that is necessary is carried out and debited to the operating account. Whereas in the past the annual renewal costs owing to the inadequacy of the passenger and freight tariffs could often not compensate for the loss of substance, it is hoped that the recent increase in these tariffs will make it possible to satisfy this need — after renewal arrears have been caught up with.

Although, no legal obligation obliges the company to include the whole of its depreciation in its annual accounts, it is its rule to do this without taking into account any possible deficit.

The serious devaluation of the Japanese currency, which was particularly rapid after the last war, led, even before the revaluation of the 1st April 1955 to include in the funds in the balance sheet besides the depreciation amount based on the purchase prices, which had become absolutely inadequate, a special supplementary item for replacement purchases, and on the debit side, additional renewal funds. As means were lacking to assure the practical efficiency of this measure, owing to the insufficiency of the passenger and freight tariffs, this intermediate solution proved unsatisfactory. Amortization has therefore been used since the 1955/56 financial year based on the new valuations. Since this date, there have only been insignificant variations in prices.

Norwegian State Railways.

The Norwegian State Railways stressed in their reply that the problems dealt with in the questionnaire sent to them were the subject of a thorough study by their Administration during the last few years.

Contrarily to the general interpretation of the questionnaire, it is stressed that the Railway Administration understands by renewal solely those replacements which do not lead to any improvement in the installations as a result of technical progress. In the case of such improvements, new capital should be invested. In other words, the sole object of renewal is to maintain the original operating capacity. Increases in this capacity as well as improvement in the output, are a question of new investments.

In the opinion of the Administration, it is not the old purchase prices which

should be taken as basis in calculating the annual depreciation, but the present real replacement values. It is only by adopting this principle that the object of the renewal policy will be attained, viz. maintaining the original investment value. In the budget proposals presented to the Ministry of Transport, the amounts asked for replacements correspond therefore to the total depreciation in every case. However, the sums generally approved for renewals are in general very much lower.

The fact that during these last decades insufficient attention has been paid to the diminishing purchasing power in fixing the annual renewal funds — due in particular to the state of the national finances — has led to an accumulation of serious arrears in renewals. The correcting of this very unsatifactory state of affairs is one of the main financial problems with which the administration is faced.

Whilst awaiting the successful outcome of its claim to receive the full amounts required for renewal according to the depreciations calculated on the replacement values, the Railway Administration has considered it necessary to keep a permanent check on evolution in this field. It has therefore instituted a special records file with perforated cards which give (for the different groups of real values liable to wear) details concerning: the initial purchase price, the actual replacement value, the age, the normal useful life, the annual and accumulated depreciation, etc.

This file however is only one part of the official records. The sums entered on the perforated cards are adjusted each year. The corrections due to fluctuations in prices are made by means of special indices which show the variation of the cost price for the different installations, etc.

Swedish State Railways.

Since 1912, the Swedish State Railways have made an annual depreciation of objects to which an unvarying value could not be attributed. The depreciation has been calculated according to the initial acquisition cost of the installations and their estimated life.

From 1937 to 1945, supplementary depreciations have been made every year, owing to the increase in prices and increased wear due to the greater traffic during these years. In the following years, this kind of depreciation was not authorised, so that the deprecitations allowed for have become more and more insufficient.

The new adjustment of the method of depreciation on the basis of the replacement values applied for the first time during the financial year 1951/52 increased the depreciation charges from 62 million crowns to 138 millions, i.e. 2.2 times greater. With this new system, it can be agreed that sums of this amount will be sufficient to conserve the value of the assets.

It can be taken that the accumulated deficiency due to the inadequate allocations from 1946 to 1951 amount to approximately 210 million crowns. The Railway Administration has recommended to the Government to catch up with this arrears by degrees. For the years 1953/54 and 1954/55, exceptional allocations of a total amount of 36 million crowns have been authorised.

Therefore, whilst in general the financing of the replacement of the installations is done by means of a depreciation account, there is no depreciation for certain items of so-called permanent value, such as lands, infrastructure including ballast, sleepers and fences; the renewal of such installations is debited in full directly to the operating account.

Nora-Bergslagen Railway.

The investment figures do not correspond to the value of renewal, but only to the actual acquisition costs. According

to the figures of the 1955 balance sheet, the investments of this railway amount to 18.8 million crowns. The cost of replacing these installations would amount to about 55.3 millions, i.e. nearly triple. The renewal funds in the 1955 budget were given as about 18.2 million crowns, but would be nearly double on the basis of renewal costs, i.e. about 34.2 millions. It is forbidden to show in the accounts any increases in value compared with the initial acquisition costs.

The sums in the renewal account based upon the acquisition values are insufficient to prevent the depreciation of the installations as a result of age and from other causes. In the opinion of this Administration, the real renewals are conditioned rather by technical necessities, progress and improvements, than by a calculated loss of substance.

Association of American Railroads.

This Association represents a free organisation, with limited and well defined powers in conjunction with the different autonomous companies. Consequently, although it dealt voluntarily with the problems raised in the questionnaire, the Association could only deal in a general way with certain parts of them.

It may be stated here that the Association includes 126 class I railways which are operated autonomously; a class I railway is one whose annual receipts amount to at least 3 million dollars.

As regards the question of financing renewals, taking into account the initial cost of acquisition and the present day replacement costs, which are the subject of the present chapter, they were only able to indicate that increases in value compared with the initial acquisition costs in the books of the Railway Administrations were not admissible. The members of the Association therefore have to get new capital when the replacement costs exceed the initial costs.

IV. The conservation of the substance of the capital invested and the decline in the purchasing power of money.

A question of particular importance in studying the problem of the conservation of the substance of the invested capital of the railway is that of knowing how the Administrations obtain funds to replace the installations which have to be renewed at much greater cost and if and how account is taken in the accounts of the Administrations of the variation in the invested capital owing to the decline in purchasing power. The questions asked in the questionnaire sent out in order to elucidate this problem, judging by the replies received, aroused great interest on most of the Railway Administrations. The profound economic and monetary upheavals which occurred as a result of two world wars, which led to all sorts of disturbances in the economic conditions between these two wars, as well as after the second world war, obliged many countries even at that time to take the consequences into account in directing their own economy, and it is to be assumed that they will not be avoided in the future in other countries.

It appears in effect that in periods of constant reduction in purchasing power, it is more and more absurd to base the calculations upon these nominal values. Calculating the depreciation of the installations at the historic prices of purchase or manufacture results certainly in the conservation of the nominal capital, but does not create conditions in which it is possible to replace the installations whose cost has gone up in the interval, which leads to loss of assets.

Erroneous and partial conceptions of the notion of the value of money and its variations in the case of accountancy lead to serious inaccuracies and too often make it difficult to conserve the capital. Now, any decline in the assets of an undertaking means a corresponding decline in the

assets of the national economy, and consequently a reduction in the social product.

The structure of the capital of a railway undertaking, with its considerable investments combined with the possibility of using, often for a great many years, costly parts of the installations, makes such an undertaking particularly sensitive to fluctuations in the value of money. There is a risk therefore in the case of railways of operating them for dozens of years without the value of the installations being accounted for in total at present levels. The difficulties will only become obvious when it will be the time for the renewals.

If we start with the idea that depreciation should make it possible to conserve the relative importance of the undertaking in the economy as a whole, and that correctly calculated depreciations represent the value of the wear and tear, it is necessary that during periods when there is a prolonged decline in the purchasing power that the depreciation amounts be calculated not on the cost at the time of acquisition or manufacture, but according to cost of replacing such installations at the present time. It is obvious that the amounts needed to buy replacements will only be available if they are covered by the product of these charges.

In effect, whilst the object of depreciation is to bring out the technical and economic wear and tear of the installations, and consequently, according to the principles of commercial accountancy, depreciation should be charged up even in the case of a deficit, the expenditure upon the renewal of the installations will necessarily always be limited by the funds available.

To take devaluation into consideration in the accounts by the depreciation charges will therefore not be a protection against loss of substance unless the amounts of the depreciations are covered by the operating receipts. In the contrary case, depreciation charges based on the present day value is at least a check which will bring out the reduction in substance that has occurred.

As it is probably forbidden by law in every country to take monetary devaluation into account as it occurs in the estimates, even in the case of capital investments, the depreciation charges in the balance sheet are generally based on nominal values, whilst « industrial » depreciation represents the real reduction in value caused by the wear and tear of the assets used in the process of production.

To take into account reductions in purchasing power which have occurred up to the time when a revaluation of the capital invested is authorised, on the debit side of the balance sheet it might be possible to introduce, if needs be beside the regularisation account, which only takes nominal values into account, a supplementary account (variation in value account) which will be credited with the sum of the difference between the depreciation according to the cost of acquisition and depreciation according to the present replacement value of the installation. In this way, the reduction in the purchasing power at the moment in question will be shown by a separate figure.

Instead of effecting a correction of the value by depreciation, the railways often set up a so-called renewals fund. This fund is credited with a theoretical sum for renewals and debited with the actual cost of renewals. This renewals fund which has the character both of an adjustment account and a reserve shows very clearly the mixture of financial and industrial accountancy, which often and logically appears on the railway. This method is based on the principle that the invested capital of the railway should be conserved in its actual substance, and that it is necessary for this purpose for the theoretical annual value of renewals to be equal to the real annual expenditure on renewals. On the railways, which have to renew their installations continuously, the

theoretical annual renewals amount corresponds to the depreciation on the replacement value calculated according to the principles of industrial accountancy.

We must not forget to point out that when calculating the depreciation charges according to the present value of the installations, the conditions prevailing are taken into account, but during periods of prolonged reduced purchasing power, the total value of the depreciation charges collected for part of the installations will in spite of everything be lower than the cost of replacing this installation when the time comes.

According to the organic theory of the balance sheet, this shortage can be made up by the increase in the actual assets procured annually by using the depreciation charges, if the undertaking has bought assets having a stable value which follows the rise in prices. If use cannot be made of this possibility, it will always be necessary to meet the deficit from capital. This is why it often happens that reserves are set aside for this purpose. Naturally, the setting up of reserves of this kind presupposes that the corresponding receipts are available. But in this case again, such a palliative cannot be used when there is a serious reduction in purchasing power unless suitable entries concerning the capital are given up.

Constant reductions in purchasing power only take away from a renewal fund its indicative value when it is impossible to assure entirely the renewals provided for. The amount of the fund will then have to be corrected by revisions of the capital charges. If under these conditions, it then becomes necessary to catch up with arrears in renewals in the following years, at higher prices than those originally necessary, it may be advisable to show the additional cost accumulated as a result separately.

Whilst it is possible to take into account temporary fluctuations in the value of money by temporary measures, prolonged reductions in purchasing power make it necessary from time to time, usually after a period of crisis, finally to eliminate inaccuracies in the balance sheet by a revaluation of capital, the new values determined in this way will then be considered as the acquisition or manufacture values.

Although purchasing power has declined very considerably in nearly every country during the last 40 years, only 4 of the Administrations questioned have been able to adjust their capital values accordingly. Probably in nearly every country, commercial legislation and still more fiscal legislation makes it essential to maintain the principle of continuity in the balance sheet. But if the purchasing power is reduced by half, for example, and if in consequence the cost of renewal is doubled, and this is not on account of a temporary disturbance of the economic situation, but rather a well defined tendency, such a continuity of the balance sheet will lead to under-estimating greatly the capital invested, with all its unfortunate consequences.

The question of the revaluation of the capital invested is therefore topical to the extent that serious reductions in the purchasing power of money occur. Naturally, opinions may differ on the importance to be attached to monetary revaluations in order to avoid makeshifts and decide to interrupt the continuity of the balance sheet and consequently adopt revaluation. In general, however, the Railway Administrations cannot act independently in this connection, and must respect the legislation of their country. However, precisely in the case of State railways properly speaking, it is possible to conceive purely and simply special regulations for Railway Administrations with their important installations, the more so as the fiscal repercussions of such a revaluation will often be of less importance than in the case of private undertakings. In all countries, there is already an idea going about that the railways are not an out of date

instrument of transport that can be put on the shelf in order to replace them by other methods, in particular road and air transport. Hence, in consequence, the imperious need to modernise railway equipment, and to do so, it is essential to show correctly in the balance sheets the assets of the railway. It is only then that we shall have sufficient knowledge to arrange for the necessary funds, whether it is a question of funds supplied by the undertaking itself from a suitable development of the receipts, or of subsidies from the State, should the latter forbid this development of the receipts through the tariffs.

In the opinion of the Reporter, an increase in values due to the reduction in purchasing power which has reached double the initial cost of acquisition of the old long term investments, clamours to be put right by revaluation.

We give below a few extracts from the replies received from certain Railway Administrations.

Austrian Federal Railways.

The decline in the purchasing power of the crown, which dates back to the Austro-Hungarian monarchy, culminated in 1925 in the introduction of the schilling on the basis of 1 schilling = 10 000 crowns, and led to a general revaluation in Austrian economy on the occasion of the establishment of opening balance sheets in gold schillings. Since 1938, there has been a further reduction in the purchasing power of money, which related ot the total capital investments of the railway, has released an increase in the replacement costs nine to ten times their initial value on the average.

The law on the opening balance sheets in schillings (Schillingeröffnungsbilanzgesetz), published in 1955 authorised Austrian undertakings to proceed to revise the figures in their balance sheet and adapt them to the new conditions of purchasing power. Although the clauses of this law did not apply directly to state undertakings, the Railway Administration will make the appropriate revaluations, in agreement with the Federal Ministry of Finances and the Court of Accountancy.

British Railways.

In spite of the reduction in purchasing power which has occurred, there has not been any adjustment of the accounts in the sense of revaluation. The additional costs of replacing installations are debited to the capital account.

The British Transport Commission is proposing to complete the depreciation charges by setting up a reserve fund, based on the increase in replacement costs, to the extent that profits will allow of such a supplementary reserve being set up. Whilst the accounts value of the installations is about £ 1 600 million, the present replacement value is about £ 5 000 million.

South African Railways and Harbours.

Since the year 1955/56, the Railway Administration, in addition to the renewal fund, has had a special account in the general reserve account to meet the increase in replacement costs due to the decline in the purchasing power of money, and to obtain greater stability in the reserve funds. It credits this account with the additional costs of replacing installations which cannot be guaranteed by means of the depreciations based on the initial cost of acquisition.

Rhodesia Railways.

Special reserve fund, created by virtue of the railway law, from whatever profits are available, can be called upon to cover additional expenditure on replacement installations which have become too costly as a result of the decline in purchasing power.

Coras Iompair Eireann.

The value of the Railway Installations was corrected to a certain extent in 1950, when the Irish railways assumed their present organisation as a public transport company, but even then this was not a well considered revaluation of the kind in mind. Since that date there has probably been a further decline in purchasing power of 20 to 30 %.

Norwegian State Railways.

The decline in purchasing power has been one of the main obstacles in the way of adopting a healthy policy of renewal. (This has already been discussed in another chapter).

The percentage of the increase in the value of the installations and rolling stock owing to the decline in the purchasing power of money between 1950 and 1956 amounts to about 50 %.

V. Correlations between the ideas of maintenance, renewal and extension of railway installations.

One of the first preoccupations of a Railway Administration as of all industrial undertakings should be not only to maintain its means of production in a good condition from the technical point of view, but also to adapt them constantly to varying conditions, and in particular to the constantly increasing demands of periods of economic prosperity. To do this, it must apply all technical progress in good time if it is not to succumb to competition from other methods of transport.

The idea of the maintenance of installations must without doubt first of all cover all the repairs and restorations needed to make possible the real utilisation of any part of the installations, at least until the expiration of the useful life attributed to it. In general, this idea of maintenance is also extended to the expenditure needed to replace and renew all the small parts of the installation.

By renewal of an installation must be understood taking out of a service an installation that has become unfit for operation and replacing it by a similar new installation. In general, such a replacement will take place at the end of the correctly estimated useful life of the installation in question. However, special circumstances may involve premature replacement, or on the contrary the installations may be kept in service for a longer period than previously estimated. This latter case generally occurs when the funds required for the replacement of the installation are not available at the desired moment, so that installations that should be renewed have to be retained in service at the cost of additional expenditure on maintenance.

Leaving such irregularities aside, there is therefore a certain relation between the maintenance and renewal costs which are theoretically the most rational. The adoption of relatively short useful lives ensures that the average maintenance costs will be low, but involves on the other hand large average estimates for early renewal. It must not be forgotten, however, that in replacing in good time installations which can still be used in other fields, the proceeds from the sale will be increased, which will correspondingly reduce the cost of replacement. It is true that in view of the particular and specialised character of railway installations, it is rarely possible to profit from this advantage.

To define the motion of renewal and replacement, we also mentioned above the equivalence of the original and replacement installations. This may require further explanatory remarks.

This equivalence may be thought of concerning :

a) the costs;

b) the kind material or technical;

c) the productivity.

If the purchasing power of money remained constant, we might be content to retain the form of equivalence *a*), because this complies with the principles of an ordered regime of depreciation in the simplest way. Modernisation, technical progress, and rationalisation in the undertakings producing railway material will result — always with the hypothesis that the purchasing power of the money remains constant — in a reduction in the cost of renewing installations of the same power, or inversely in an increase in their productiveness for the same cost. This increase in capacity at the time of replacement in case *a*) is merely a secondary consequence for which we can only be thankful.

If there is a decline in purchasing power, which has been the case in nearly every country, although to very varying degrees, solution *a*) will result in unfavourable results, the more so the longer the useful life of the installations is, or has been, estimated to be. Doubtless it will only be very rarely that case *b*) can be used, as in nearly all fields technical progress is such that the old models to be replaced are no longer made to day except in a very few rare cases.

The only economically correct method, even when the purchasing power is on the decline is to use case *c*). This also gives us the definition of the third notion quoted in the heading, that of the extension of the installations, i.e. the purchase of additional installations unrelated to taking out of service other installations, or again the purchase of powerful installations in correlation with the renewal of less powerful installations.

Nearly all the Railway Administrations may introduce in their accountancy regulation tolerances for the booking to maintenance or to renewals, or extension of installations; in virtue of these regulations, expenditure below a given level, generally a small sum it is true, comes under the heading of maintenance.

This diversity of the methods of entering renewals, which we mentioned in another chapter of the present report, is certainly due to the diversity in the systems of accounts and preparation of the budgets. These in their turn can be explained by the historical evolution of the systems and the closeness of the relations between the railway budgets and the State budgets, or at least in the legal dispositions influencing free decisions, in particular the regulations governing companies and the fiscal laws.

VI. The present condition of the railways installations and intentions regarding their modernisation in the near future.

Nearly all the Administrations replied more or less forcibly in the negative when asked if the condition of the railway installations and equipment of the lines corresponded to the present state of technique and transport requirements. The events of the war and those of the post-war years, in their own countries, but also the repercussions of international tension on the national economy, as well as the accumulated needs for financing the modernisation and increase in productivity in numerous domains of the national economy were quoted as the main reasons for the inadequacy of present railway equipment. The fixed installations and in particular the rolling stock have been used to the limits of their capacity and subjected to exceptional wear amounting to abuse. After the war in many countries, in addition to a shortage of financial means, there was an appreciable shortage of materials, which made it impossible to catch up very quickly with arrears in replacements. Often it was the economic policy of the State, in a general way, and more particularly the wages and prices policy which led the State to forbid the Railway Administrations to fix tariffs which would cover the costs, and in many places it was possible to speak of excessive social tariffs in

the passenger services and tariffs subsidising certain branches of the economy in the case of the freight traffic. As a result, the financial situation of the Railway Administrations deteriorated considerably, and led to further postponements of the work of modernisation, which however was becoming a more and more pressing need owing to the competition of other transport methods.

The replies received show that the Railway Administrations are convinced that the realisation of their long term investment programmes is the most suitable means of systematically eliminating the delays in technical development, which are seriously handicapping their operating, and would enable them to satisfy the increased traffic demands of the present day under economic conditions.

These investment programmes are generally spread over a period of 5 to 10 years, sometimes 15, and provide, in addition to enormous improvements to the fixed installations, the replacement of steam traction by Diesel or electric traction. Widescale modernisation of the stock of wagons and coaches is generally also provided for at the same time as this change in the traction. Although the replies gave no details on this subject, it can be seen that the conversion of the traction depends on the one hand on the power position in the country concerned, and on the other on the estimated profits from this measure; this latter consideration operates in favour of electric traction on hilly lines with heavy traffic, and in other cases in favour of Diesel traction in the place of steam traction.

The modernisation of the fixed installations is intended above all to obtain faster running speeds. This is the essential object of the reinforcements needed to the permanent way, the elimination of too pronounced curves, the improvement of the safety installations profiting by the technical progress made in this field, whilst economising in labour, organising modernised marshalling yards to make up the trains and consequently speed up the freight traffic, as well as the modernisation of the telecommunications installations.

The proposed investment programmes, some of which have already been embarked upon, require the different Railway Administrations to spend capital sums varying from 50 to 3 000 million USA dollars. Although the replies did not expressly underline this point, it is to be presumed that in many cases these investment programmes are still only the projects and intentions of the Railway Administrations, which certainly will not recoil from any effort to procure the considerable capital needed; they are not modernisation programmes the financing of which is already settled. In particular, in those countries where the railway budget is part of the national budget, or closely related to this budget, certainly great efforts will have to be made and remade every year to obtain the funds required for the different annual portions of these programmes.

VII. Conclusions.

The accounting of the capital invested and the accountancy values in relation to the conservation of its value takes place in very different ways on the different Administrations. This diversity is due to the total absence of any statement of assets suitably subdivided until the revaluation of the invested capital on the books of the Administrations in terms of the present purchasing power, instead of invested capital based on historical values dating from epochs with the most varying purchasing powers of money.

The accounting of the expenditure required for renewals to conserve the substance takes place by debiting directly the operating account with the actual renewal costs, or with the sums theoretically necessary to endow a renewal fund, or with the depreciation charges credited to a regularisation fund.

In view of the fact that the situation from the point of view of the receipts is often unfavourable, only a small number of Railway Administrations succeed in obtaining from the receipts the funds required for the material renewal of the installations. Frequently, it is charges that have nothing to do with the operating imposed upon the Railway Administrations when they held a monopoly of transport, and the intervention of the State in fixing the tariffs at low levels that have an unfavourable effect upon the railway receipts. Now, these Administrations cannot prevent their budgets being swollen by the increased wages of their staff and salary increases and price increases which affect the products they consume. In addition, the ever increasing competition of other methods of transport obliges them to catch up as quickly as possible with delays in renewals and to give increased attention to the modernisation and increased efficiency of the organisation of transport.

Correctly to appreciate the financial situation and future capital requirements, it is essential to draw up accounts showing the value of the capital invested, taking into account the reduced purchasing power of money.

Without such a revaluation, which should be authorised by the laws, in all economic fields where purchasing power has been seriously reduced, the owners, associates, share-holders or backers of all undertakings, especially those with heavy capital investments, will end by being misled as to their true economic situation in which the State itself cannot be disinterested, either as owner of the undertaking, as is the case with many railways, nor as financial administrations concerned with the rationalisation of the economic life of the country.

The very brutal interventions in the regime of renewal and modernisation of the railway which have taken place in many Railway Administrations owing to the general financial situation of the State, will have the effect in the not so far off future of leading if not to the extinction of the railway, which in spite of all competition remains the most important instrument of transport of a country, at least to seriously compromising the capacity of this method of transport, and above all its safety of operating. It would be a very short sighted economic policy to remain blind to the problems of the economy of transports, precisely in periods of an expansion of world economy which involves costly improvements and modernisation of the industrial and commercial undertakings of a country in order to make higher output possible.

The freeing of the operating budget from charges that are alien to it and transferring them to the competent institutions benefiting from or responsible for them, indemnifying the railway for tariff facilities which exceed its commercial interests, granted for reasons of social policy or having the character of subsidies to favour the general economy at the expense of the railway, and an equitable co-ordination of transport which takes into account the correct utilisation of the different methods of transport, should, in conjunction with a judicious support of the financial efforts of the railways to modernise and increase the output of their undertaking, contribute towards solving the problems of the economy of transport in the near future.

[625 143. 3]

INTERNATIONAL RAILWAY CONGRESS ASSOCIATION

17th. SESSION (MADRID 1958).

QUESTION 9.

Experience obtained concerning the undulatory wear of rails.

— Damaging effects on track, bridges, viaducts and tunnels, and on the rolling stock.

— Research into the causes of this kind of wear.

— Measures taken to avoid or to remedy it.

REPORT

(America (North and South), Australia (Commonwealth of), Burma, Ceylon, Egypt, India, Irak, Iran, Republic of Ireland, Japan, Malaysia, New Zealand, Norway, Pakistan, South Africa, Sudan, Sweden, Union of Soviet Socialist Republics and the United Kingdom of Great Britain and Northern Ireland and dependent overseas territories),

by N. C. VOGAN,

Chief Civil Engineer, New South Wales Government Railways Sydney.

FOREWORD.

The Questionnaire sent to thirty-three (33) Railway Administrations has been replied by twenty-two (22) only. The Sudan and Malayan Railways were unable to report owing to shortage of professional staff. Iraq, Argentine, Tasmania and Sweden Nora-Bergslagan Railways were unable to reply, as time did not permit. Rhodesia, Jamaica and Nigerian Railways stated they were not in a position to reply. Nordmark-Klaralven and Svenska-Jarnvagsforeningen Systems are covered by a report from the Sweden State Railways. Norway has no experience concerning these problems.

The replies received from the following Administrations, have been summarised in this report :

Indian Railway Board;
Victoria Government Railways;
Japanese National Railways;
British Transport Commission (Railway Division);
East African Railways and Harbours;
Sweden State Railway Board;
New Zealand Government Railways;
South African Railways;
Association of American Railways;
Eire : Coras Jompair Eireann;
London Transport Executive;
New South Wales Government Railways.

Summary of Section I.

GENERAL.

Undulatory wear is divided principally into two groups : « A » known as « roaring rails » or « washboard track » and « B » sometimes described as « saddles », which are of a much longer pitch.

Both types of undulatory wear are illustrated in the set of photographs attached herewith.

Type « A » occurs invariably in all Systems under steam traction, on straight track and flat curves of approximately 30-chains (2° — 53′) radius and over.

The pitch of the undulation usually varies between 1 1/2 inches to 2 1/2 inches (38 mm to 64 mm) with depths to 0.015 inches (0.4 mm).

The rail running surface has a mottled appearance — transverse bands of extreme hard steel structure. These bands exhibit high polished spots of « martensitic » structure and occur in single or double parallel rows. These hard spots extend to depths in the rail surface, which with heavy grinding cannot be entirely eliminated. London Transport reports grinding as a normal maintenance process and this has proved satisfactory in keeping corrugations under control.

British and South African Systems have reported experiencing this type of undulatory wear, but attribute the primary cause to « sorbitising » of rails. Many of these sorbitic rails corrugated very badly, but since their replacement, wear of this kind is no further a problem. Sweden reports rare cases of corrugated rails and have attributed the cause to the vibration during rolling operation in manufacture.

Type « B » usually occurs on sharp curves of less than 20-chains (4° — 20′) radius, and on track mainly used by electric multiple-unit passenger trains. The pitch is much longer, varying from 5 to 60 inches (13 to 154 cm) with depths up to 3/16 of an inch (5 mm) or more.

The texture of the running surface is comparatively smooth with a semi-shiny lustre and is more or less similar over the crest and the trough. The surface hardness over the peaks and troughs is practically the same. Extrusion of the metal is very apparent particularly on the outside face of the head along the troughs, which suggests wheel slip.

India, East Africa, Sweden and Eire have reported no problem regarding this type of undulatory wear. These countries appear to confine their remarks to steam traction only, which associates with the Type « A » (roaring) corrugations.

The undulatory wear on the two lines of rails of the same track for Type « A » (roaring) corrugations is similar in pattern and occurrence, in practically all Systems, particularly on Straights. On flat curves the tendency is for the markings to be more clearly defined on the low rail.

Japan has observed that corrugations on straights follow various patterns — some with corrugation on rails opposite one another, varying to the troughs being opposite high spots. This could be due to local rail creep.

For Type « B » (saddles) — undulatory wear is reported to occur more on the low rail than the high. The opinion has been expressed that primarily the low rail corrugates and is sympathically transferred to the high rail.

Regarding the effect of speed on corrugations the majority of Systems report no relationship, or very little, between pitch and depth of the undulations and the average speed of trains — Victoria, South Africa and the American Railroads admit no evidence in this regard. On the other hand New South Wales is very definite that pitch varies with the average speed for type « A » corrugations — the higher the average speed the smaller the pitch. No relationship between speed and depth has yet been observed.

The first sign of undulatory wear seems to appear within three (3) months of laying of track. This is more evident in the Type « B » undulatory wear, which could be attributed to the greater intensity of traffic where multiple-unit electric passenger rolling stock is used. New South Wales reports rails (low in carbon) used on 12-chains (7° — 14′) to 20-chains

(4° — 20′) radius curves, under multiple-unit electric traction, being replaced due to bad « saddling », fifteen (15) months after laying.

The growth of undulatory wear of the « roaring type » has been observed to commence with a narrow shiny strip appearing longitudinally along the running surface, developing into « scallop » formation with shiny spots appearing and ultimately forming into transverse ridges, with very hard « martensitic » peaks. Observations made by New South Wales indicate that softer rails corrugate at less rate than hard rails.

Regarding the growth of Type « B » (saddling), very little data is available. South Africa and London Transport reports uniformity of undulation in relation to sleeper spacing. Crests occuring in the first quarter between sleepers and troughs in the last quarter. New South Wales report that this type of undulations are irregular and follow no particular pattern. First indications are high polished spots at varying pitch, with slight overflow of metal on outside edge of head of rail, between these high spots. Ultimate mushrooming effect is fairly general along the troughs.

There is a diversity of opinion regarding the effect of fishplated joints on the regularity of undulatory wear. Although some Systems agree that joints have an effect, they are not consistent in their findings. Most countries are in accord that fish joints promote to some extent variation of frequency and depth of Type « B » (saddled) undulations. New South Wales System observed the depressions, in the early stages deeper on the receiving side of joint, with very pronounced « saddles » apparent on the high rail of a curve about 5-ft. in advance of the joints on the low rail.

Practically no information is available concerning the effect of reversing or transposing corrugated or « saddled » rails. New South Wales has carried out tests by re-using corrugated rails on sharp curves with good results. These rails were corrugated to depths of 0.015″ and relayed in a single two-way track, on curves of 16 (5° 25′) and 20-chains (4° 20′) radius approximately five (5) years ago and, today the corrugations have almost entirely disappeared.

The only information regarding grinding and heat treatment has been supplied by New South Wales. Grinding of rails was carried out to just below the original troughs and the rail then heat treated. After three (3) months in service the corrugations re-appeared in the identical spots where the original peaks existed.

The effect of heating during welding of joints has been the cause of light undulations in the proximity of the joint and is assumed to be due to variation in hardness within this zone. This effect is very noticeable in steam tunnels, where affected by fume and damp atmosphere.

Comparing rails having undulatory wear with those which have none, it is experienced in Victoria and New South Wales that rails with undulatory wear, particularly those of the « saddled » type, have a higher incidence of failure.

Section I.

GENERAL.

QUESTION 1.

Are all types of undulatory (corrugated) wear fundamentally similar or have different types been noticed?

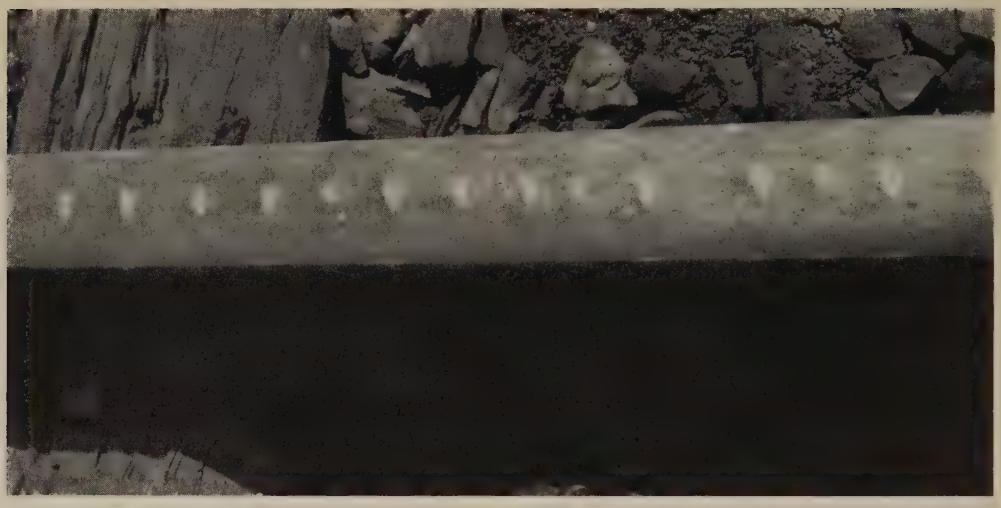
Have you made any classification of the different types of undulatory wear?

Any statistical data?

The undulatory wear in rails differs in many respects, but can be classified into two (2) major types.

Type A. — Commonly termed « roarers » or « washboard » corrugation. The running surface has a mottled appearance with high shiny peaks, varying 2″ — 3″ centres.

Type B. — The top surface of the rail head is deformed into series of undulations « saddles » with a more or less uniform semi-shiny surface. The distances between the peaks vary from about 5 to 60 inches.



Typical short patch (washboard) type of corrugation, Sydney-Newcastle line.
New South Wales Railways.

Typical corrugation under electric traffic (Saddling), North Shore Line.
New South Wales Railways.

Most Systems have classified the types of undulatory wear, but statistical data is practically nil.

INDIA.

All similar and exhibiting high bright spots. Classification made as to shape and size of high spots, location on rail, whether in single or double rows, depth and pitch of corrugation — Metallurgical features not yet made.

VICTORIA. 3 Types.

Type A. — Rail running surface has mottled appearance — transverse bands of extremely hard steel structures — cold working of softer rail surface between them. Commonly termed « roaring rails » or « washboard track ».

Type B. — Rail head deformed into series of undulations — without serious alteration in steel structure — bright running surface — « Electric Traction Corrugation ».

Type C. — Deformation occurs on rail head and on occasions into web and flange. Pitch is not constant and defect is result of some form of defect in rail, pipes, laps, etc.

JAPAN.

Observed two (2) types — corrugated wear and undulatory bend in ratio of 2 to 1 — varying wave length — 5 cm (2″) to 150 cm (60″).

Not made any classifications only for some statistical observation.

BRITISH RAILWAYS.

Wide variety of patterns and wave lengths. Found frequently under corrosive conditions as in tunnels or at ends of water troughs. Peaks become dried out as wheels merely make contact at peaks, leaving water in the troughs or valley to corrode the rail.

Vast majority of rails on British Railways do not corrugate. Only « sorbitic » rails now nearly all removed from the track. These were found to be prone to corrugation.

Battering of rails is formed on electrified tracks with electric trains having heavy unsprung masses. Consist of irregular depressions on running surface due to plastic formation of steel — no formation of « martensitic » on peaks.

Battering has been observed to start at running-on end of a rail associated with vibration of wheels passing over joint.

Victorian Railway, — Survey of type « A » (roaring) rail corrugation.

	Rails mainly laid in secondary main lines and branches	Rails laid in main line, steam and Diesel traction	Rails principally confinded to electric-traction tracks	Totals
Weight of rails in lbs. per yard . .	60 and 75	80, 90 and 94	100, 107 and 110	
Miles of rails in running track . .	5 116	4 314	532	9 962
Miles of rail affected by corrugation	131	799	3	933

Instances where corrugation starts in mid rail — wheel burns do not start formation of corrugation.

EAST AFRICAN RAILWAYS.

All cases fundamentally similar. Pitch varying 3/4 inches to 3 1/2 inches — depths 0.003 to 0.006 inches. Some deeper to 0.010 inches.

No classification. — No statistical data.

SWEDEN.

Corrugated rails very rare. Observed over approximately 13 km on one line Southern Sweden, soon after new rails layed, that when thin surface skin was worn away bright spots were visible — German rail manufacturer admitted corrugations were due to vibrations during rolling — accepted that this was cause of corrugation.

No classification. — No statistical data.

NEW ZEALAND.

Spacings vary 2 inches to 60 inches (5 — 150 cm) — depths from few thousands of an inch to 0.062 inches (1.6 mm) — vertical deformations attributed to inherent defects in new rail. No statistical data available.

SOUTH AFRICAN RAILWAYS. - 4 Types observed.

(*a*) Short (roaring rails) — pitch 7 to 10 cm (2 3/4 inches to 4 inches) only on « Sorbitic » rails where top surface is cooled by watersprays, use of these rails discontinued — problem now negligible.

(*b*) Long irregular pitch — depth to 3 mm (1/8 inch) on straigths and curves — whole rail bent vertically, due probably to gag straightening of rails — now negligible with roller strainghtening.

(*c*) Compound corrugations — pitch 7-12 cm (2 3/4 to 4 3/4 inches) superimposed on corrugations with pitch about 30 cm (12 inches) — depth 1 mm (0.039″) found on some steel bridges — probably due to bridge vibration — short corrugation ascribed to wheel chatter due to braking — noisy, but has not otherwise been found deleterious, it can probably be reduced by the use of rubber pads.

(*d*) Long corrugations of regular pitch — equal to sleeper spacing 55-90 cm (22 to 35 inches) 3 mm (1/8 inch) deep — when it reaches 4.75 mm (3/16 inch) rails are replaced to prevent jumping of pantographs of electric locomotives.

This is the only type of corrugation at present giving serious trouble.

Note. — In replies to Questions only type (*d*) corrugations will be considered.

ASSOCIATED AMERICAN RAILROADS. 2 Types.

(1) Light curve and tangent tracks — corrugations shallow and closely spaced, 2 1/2 to 3 inches (6-8 cm) apart.

(2) Low rail of sharp curves, 6 to 8 inches (15-20 cm) long and deeper — heavy superelevation.

Neither is a serious problem in United States of America.

EIRE.

Fundamentally similar — corrugations differ only in degree and spacing — no classification made.

NEW SOUTH WALES.

No, there are two (2) major types.

Type A. — Which occurs only on straights or flat curves and has a pitch of about 2 inches (5 cm) with shiny crests. Commonly known as « roaring » rails.

Type B. — Of longer pitch, varying 5 to 30 inches (13-80 cm) in pitch with no shiny crests. Occurs only on sharp curves. Commonly known as « saddles ». Occurs on tracks mainly used for multiple unit-electric traction.

NORWAY.

In two (2) long tunnels « roaring » rails have formed in moist places and can be ground out — no other experience.

Corrugation forming on A.I. & S. 107-lb rails laid in February, 1954. Sydney-Newcastle. New South Wales Railways.

(Rubber pads and elastic rail spikes.)

Showing rubber squeezing up between rail foot and plate shoulder. Sydney-Newcastle. New South Wales Railways.

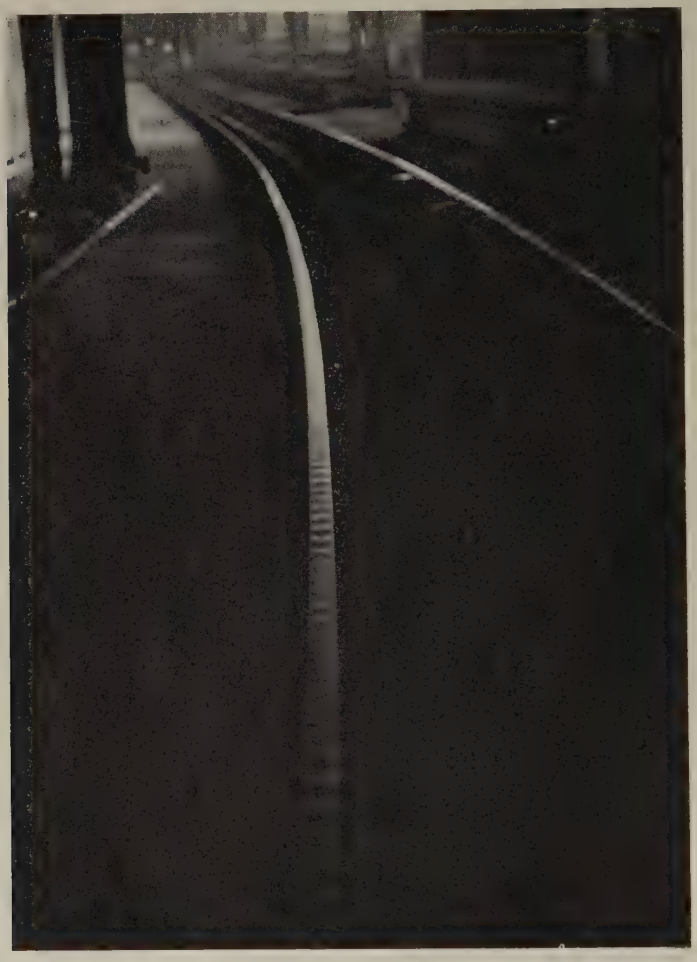
LONDON TRANSPORT.

Two (2) types of undulatory wear are experienced and they appear to be fundamentally different.

Type A. — Corrugations (roaring) — pitch 2 inches to 6 inches (5-15 cm) with depths to 0.010 (0.3 mm) and give rise to noisy running.

Type B. — Battering (saddles) — pitch 24 inches to 60 inches (60-150 cm) with depths up to 1/8 inches (3 mm).

* * *



City Outer (Circular Quay to St. James). New South Wales Railways.
Short pitch (4") corrugation.
(Rails in service since January, 1956.)

QUESTION 2.

Relative values of the different types of undulatory wear from point of view of the frequence with which they occur,

their extent, etc. — taking into account the length of the undulatory wave, its amplitude, the surface structure of the metal, etc.

* * *

City Inner (Circular Quay to St- James). New South Wales Railways. Showing short pitch corrugation and long pitch (Saddling) in background.
(Rails in service since January, 1956.)

Majority of the Systems are in agreement that undulatory wear differs in many respects, but there are two (2) types which appear to be more generally experienced. These have been more or less classified by most of the Systems reporting and will be known as Type « A » and Type « B ».

Type A. — Commonly termed « roarers » or « washboard track » — and occurs practically in all cases under steam traction on straight track, and also on flat curves beyond approximately 30-chain (2° — 53′) radius. The rail running

surface has a mottled appearance — transverse bands of extremely hard steel structures. These bands exhibit high polished spots of Martensitic structure, which can occur in single or double parallel rows and with further cold working will extend to depths in the rail surface which, with heavy grinding, cannot be entirely eliminated. Troughs are usually dullish in appearance and metal much softer. The pitch of undulation of this type usually varies from 1 1/2" to 2 1/2" inches (38 mm to 64 mm) with depth varying to 0.015 inches (0.4 mm) in extreme cases to 0.020 inches (0.5 mm).

British and South African Systems have reported experiencing this type of undulatory wear, but attribute the primary cause to « sorbitising » of rails. Many of these sorbitic rails corrugated very badly and since their replacement, wear of this kind is no further a problem.

In Sweden corrugated rails are very rare, only one case of approximately 13 km is reported. These corrugations were observed immediately after the first rail was laid in 1943. The characteristic light spots appeared soon after the skin of metal wore away and investigation by the German Manufacturer, attributed cause to the vibration during rolling operations.

Associated American Railroads reports that although corrugations of this type exist, it is not a very serious problem on most railroads in America.

Type B. — « Saddled » rails — this type usually occurs on sharp curves on track mainly used by electric multiple-unit passenger trains. The pitch is much longer, usually varying from approximately 5 to 60 inches. Depth of these undulations varies to as much as 3/16 of an inch. The texture of the running surface is comparatively smooth with a semi-shiny lustre and is more or less similar over the crests and troughs. The hardness of the surface over peaks and troughs is almost the same. Extrusion of the head metal is very apparent, particularly on the outside face of the head along the troughs.

India, East Africa, Sweden and Eire have reported no problems regarding this type of undulatory wear. These countries appear to have confined their remarks to Steam traction only, which is associated with « roaring » type of corrugations.

On the other hand this « saddling » is giving serious trouble in South Africa, whereas the « roaring » type is negligible. No statistical data has been given in any of the reports.

INDIA.

Statistical data not yet available.

VICTORIA.

Type A. — « Roaring » rails 933 1/2 miles of rail affected in 1955. Amplitude from 0.001 to 0.010 inches. 90-lb. rail mainly affected. Steam and Diesel Traction.

Type B. — Electric traction track and then only under specific conditions of track support and curvature. Length to wave 3 to 36 inches. Amplitude from 0 inches to 1/4 inches.

Type C. — Due to rail defects; occurs anywhere. Varying amplitude and wave length.

JAPANESE RAILWAYS.

Wave lengths around 500 mm (20 inches) are most frequent and depths between 1 mm to 2 mm « roaring » type occur about double those of the « saddle » type.

Pitch 500 to 1 000 mm most frequent at speed of 40 km per hour.

BRITISH RAILWAYS.

Not regarded as vital since nearly all corrugated « sorbitic » rails have been removed. Normal rails in those not « sorbitised », which had become corrugated, amount to about 3 % of the running line.

See general report and « roaring rails » by Turner.

EAST AFRICAN RAILWAYS.

No information.

SWEDEN.

Only one (1) type of rail corrugation, pitch about 45 mm and depth less than 1 mm.

NEW ZEALAND.

Undulatory wear not uncommon. Most prevalent is « wavy », which can occur in most weights of rails at periods of 5 to 60 inches and to a depth of 0.062 inches. Not considered serious problem on track or rolling stock.

No data.

SOUTH AFRICAN RAILWAYS.

Covered under question (1).

ASSOCIATED AMERICAN RAILROADS.

The closely spaced type on tangent track and light curves is most prevalent. The second type confined to sharp curves with heavy superelevation.

EIRE.

No information.

NEW SOUTH WALES.

(A) « *Roarers* ».

2 to 3 inch pitch — almost continuous over straights and flat curves of similar type of track. Depths variable to 0.015 inches — in few cases as much as 0.020 inches.

The higher peaks are hard and polished with a dull surface between.

(B) « Saddles » — in the top running surface at pitch varying mostly between 18 to 36 inches with depths in the vicinity of 3/16 inches.

They occur on sharp curves, electric traction on rising and falling grades, but more extensively on rising grades. They vary, in frequency, around a particular curve.

The troughs of the « saddles » are semi-polish similar to the peaks. Wheel slip apparent.

(C) Short « saddle » rails varying 5 to 8 inches pitched mainly on curves on concrete road bed. Surface has a sheen appearence. Depth varying too 0.020".

LONDON TRANSPORT.

Type A. — Corrugations — occur over considerable portion of the System, but are removed by grinding.

Type B. — Which is common on curves of radius less than 10-chains.

QUESTION 3.

Where do the different types of undulatory wear occur, for example on straight sections or curves? In the case of curves, between what limits of curvature.

Type A. — (Roaring undulation.) Is generally confined to straight sections and flat curves of 30-chain (2° 53′) and over. Victorian Railways have reported the minimum radius of curve affected as 100-chains (0° 52′). American Railroads also experience these corrugations on straight and light curves — no limits of curvature given. In East Africa and Sweden where this type of undulatory wear only is experienced, have reported that these corrugations occur on sharp curves as low as 15 chains (5° 47′) to 18 chains (4° 49′) radius.

Type B. — (Saddles.) On practically all Railway Systems where they occur, this type of undulatory wear is confined to sharp curves of less than 20 chains (4° 20′) radius.

INDIA.

Greater incidence of corrugation on straights than curves. No cases of curve sharper than 2° (43 chains) radius having corrugation, have come under notice.

VICTORIA.

Type A. — Confined to straights. Some transition curves and flat curves above 100-chains radius.

Type B. — Inner rail of sharp curves, sometimes sympathetically transferred to outer rail. Most frequent 8-chains to 20-chains radius.

JAPAN.

Principally on straights and on flat curves of 500 m (25 chains) radius or over.

BRITISH RAILWAYS.

Not specified.

EAST AFRICAN RAILWAYS.

Straights, curves up to 5° (20 chains) radius and mainly on one section of line extending about 100 miles inland from the Coast.

SWEDEN.

Straight sections and on curves radius of more than 300 m (15 chains) radius.

NEW ZEALAND.

More frequently on grades subject to severe braking and track forces. Damp atmospheric conditions and high lengths on curves.

SOUTH AFRICAN RAILWAYS.

Long corrugations on harp curves, steep electrified lines and, to a lesser degree, steep steam lines and heavy traffic.

Curves below 300 m (15 chains) radius most affected.

ASSOCIATED AMERICAN RAILROADS.

Closely spaced corrugations on tangent track and flat curves. Undulatory wear: Second type, sharp curves 3° and over and where heavy superelevation.

EIRE.

Principally on straights and on flat curves of 400 m (20 chains) radius or over.

NEW SOUTH WALES.

(*a*) On straight and flat curves above 30 chains (2° 53′) radius.

(*b*) On curves (electric traction) under 20 chains (4° 20′) radius.

(*c*) On curves, tunnels on concrete bed (electric traction) under 20 chains (4° 20′) radius.

LONDON TRANSPORT.

Type A. — Corrugations — appear almost inevitably at and on the approach to stations, where brakes are applied heavily, also on some curves where braking is not normal.

Type B. — Appear on curves with a severity roughly to the square of the radius and occasionally on Down grades where brakes are applied.

* * *

QUESTION 4.

Comparison of undulatory wear on the two lines of rails of the same track; on curved track and on straight track.

The undulatory wear on the two lines of rails of the same track for Type A (Roarers) corrugations is similar in pattern and occurrence, in practically all the System, particularly on straights where the markings are similar on both rails. On flat-curves, the tendency is for the markings to be more clearly defined on the low rail. Sweden reports that the outer rail only develops corrugation, elliptical in shape with long axis in same direction as the rail. The ellipses vary with radius of curve — the sharper the radius the thinner the markings. Japan has observed that the corrugation on straights follows various patterns — some with corrugations on rails opposite one another, varying to the troughs, being opposite high spots. This could be due to local rail creep. There are also a number of locations where one rail is heavily corrugated whilst opposite rail is quite smooth. This condition is also reported by India and New South Wales Systems.

For Type B (saddles) undulatory wear, on curves, four countries reported that undulatory wear occurs more on the low

rail than the high. The opinion has been expressed that primarily the low rail corrugates and is symphathically transferred to the high rail.

South Africa reports that undulation is worse on the outer rail on a curve with the outer edge of the head also exhibiting the wavy appearance.

INDIA.

No bias in favour of outer or inner rail of a curve. Many cases where one rail in a track (either single or double line) exhibits undulatory wear.

VICTORIA.

Type A. — (Roarers.) No difference on straights; very little difference on curves, except bright spots on the outer rail not so clearly defined.

Type B. — (Saddles.) Occur usually on inner rail of sharp curves, but may be sympathetically transferred to outer rail. Observed limit of curvature 8-20 chains radius.

JAPAN.

Type A. — Various patterns have been observed on straights, corrugation of right hand rail being opposite to the left hand rail.

Type B. — Where the corrugation pattern is parallel.

Type C. — Where the pattern is staggered.

Type D. — Where one of the two (2) lines is worn horizontally.

On curves report shows undulatory wear on inside rail more than on the outside one.

BRITISH RAILWAYS.

Not specified.

EAST AFRICAN RAILWAYS.

Undulatory wear occurs on each rail of straight and curved track.

SWEDEN.

On straight track corrugation occurs on two (2) lines of rail with the same pattern — ellipitical bright spots.

On curves, corrugations disappeared on inner rail, but remain on outer rail.

Shapes of ellipses vary with the radius of the curve, ellipses gets thinner in shape with the decreasing radius of the curve.

On curves with a radius of about 600 m (30 chains) the series of ellipses thus are transformed to a thin broken line on the middle of rail head. With a radius of 300 m (15 chains) these lines have disappeared completely.

NEW ZEALAND.

Straight track; may occur on either rail only. On curves undulatory wear of the low leg not recorded. This may be due to the fact that most of our traffic runs at below equilibrium speeds and hence the outside wheels would tend to slip.

SOUTH AFRICAN RAILWAYS.

Corrugations found on both rails of curves. Generally, not to a similar extent at similar positions found on outside of outer rail as well as on the top running surface.

ASSOCIATED AMERICAN RAILROADS.

Some on both rails. Sharp curves, corrugation noticeable on low rail, but not on high rail.

EIRE.

No noticeable difference.

NEW SOUTH WALES.

(*a*) Both rails same for straights — more distinct on low rails of flat curves.

(*b*) Principally low rail of curves.

LONDON TRANSPORT.

Type A. — Occurs on both rails of a curve, but appears quickly and is more pronounced on the outer rail.

Type B. — Occurs on either rails, but on sharp curves less than 10-chains radius, where check rails are fitted battering develops on the low rail.

* * *

QUESTION 5.

In the case of wear known as « roaring rails », what is the range of the pitch and depth of undulatory wear? Does the pitch and depth vary with the average speed of the trains that run over the line in question?

The range of pitch generally is between 1 1/2 inches to 3 1/2 inches (4 to 9 cm) with depths varying to 0.015 inches with occasional extreme cases to as much as 0.020 inches. India and the American Railways report a wider range of pitch, from 1 to 6 inches (2.5 to 15 cm). (India reports instances as low as 1/2 inch with varying depths in extreme cases to 0.025 inches.

Majority of the authorities report no relationship, or very little relationship, between pitch, depth and the average speed of the trains that run over the section of the track in question.

Victoria, South Africa and the American Railroads, admit no evidence in this regard. On the other hand New South Wales are very definite that pitch varies with the average speed — the higher the average speed the smaller the pich. No relationship between speed and depth has yet been found.

INDIA.

Pitch varies 0.5 to 6 inches with depths as much as 0.025 inches, no connection has been found between pitch and depth. Speed has no effect on phenomenon of corrugation, nor pitch and depth be related to speed.

VICTORIA.

Type A. — « Roarers. » — No evidence that pitch and depth vary with the speed of trains. Pitch varies between 0.25 and 3 inches. Depths vary between 0.001 and 0.010 inches.

JAPAN.

Average speed of trains bears little relationship to the pitch and depth of undulatory wear.

BRITISH RAILWAYS.

No particulars.

EAST AFRICAN RAILWAYS.

Pitch varies 3/4 to 3 1/2 inches; depth mainly 0.003 inches to 0.006 inches, some up to 0.010 inches. No recorded relationship between pitch, depth and speed.

SWEDEN.

Do not specify any relationship between speed and amplitude. Pitch 45 mm (1.75 inches) with depths less than 1 mm (0.039 inches).

NEW ZEALAND.

Unable to define any relationship to speed.

SOUTH AFRICAN RAILWAYS.

Only occur on « Sorbitic » rails. Pitch 7 to 10 cm (2 3/4 to 4 inches) depths 0.2 to 0.4 mm (0.08 to 0.16 inches). No particulars concerning relationship depth, pitch and speed.

ASSOCIATED AMERICAN RAILROADS.

No evidence that pitch and depth varies with the speed of trains. Range of pitch and depth 1 1/2 to 6 inches and .005 inches to .012 inches respectively.

Pitch and depth as above was found to occur in the same rail length.

EIRE.

Speed of train within limits does not appear to be a fact of any consequence. Very few measurements have been made.

NEW SOUTH WALES.

« Roaring » rails — pitch 2 to 3 inches with depths varying to 0.015 inches — pitch

and depth vary with average speed — at high average speeds pitch decreases.

LONDON TRANSPORT.

No information.

* * *

QUESTION 6.

Formation and evolution of undulatory wear.

(a) « *Time between the laying of the track and the appearance of the first sign of undulatory wear.* »

Type A. — « Roarers. » — Corrugations — Victoria, Japan and New South Wales are the only Systems, which have given definite information regarding time between laying and the appearance of the first sign of undulatory wear. It varies 3 to 12 months depending on locations, etc. India and Sweden have reported that corrugations are observed when rails were laid. These facts appear to be loosely given with very little evidence to back them up.

Type B. — « Saddles. » — This undulatory wear is reported to be in evidence, earlier than three (3) months in some locations. New South Wales reports soft rails (low carbon) were replaced within fifteen (15) months of laying. These were on 12 to 20-chains radius curves under multiple-unit electric traction.

(b) « *The pattern of undulatory wear from its beginning and its growth.* »

Type A. — « Roarers. » — Very little data regarding pattern and growth has been submitted. It has been observed that a narrow shiny strip appears along the running surface, developing into scallop formation with shiny spots appearing and ultimately forming into transverse ridges, with very hard Martensitic peaks and dull surface troughs of softer metal.

Observations made by New South Wales indicate that softer rails corrugate at less rate than hard rails. No tests are available as yet to ascertain comparison of rate of growth of hard and soft rails.

« Saddled » type — South Africa and New South Wales are the only countries commenting. South Africa reports that the crest of this type of undulatory wear commences between sleepers, whereas in New South Wales they follow no particular pattern. The mushrooming effect is fairly general in the troughs.

(c) « *Whether the existence of a joint has any effect on the regulatory of undulatory wear waves.* »

Type A. — « Roarers. » — There is a diversity of opinion regarding the effect of fish joints on the regularity of undulatory wear. Although some Systems agree that joints have an effect, they in themselves are not consistent in their findings. Some report that joints promote corrugation, whilst others state that they iron out considerably for some distance to re-appear further along the rail.

Regarding type B (Saddled) rails most of the countries concerned with this type are in accord with the finding that fish joints promote to some extent variation of frequency and depth of this type of undulatory wear. New South Wales System observes the depressions, in the early stages, deeper on the receiving side of the joint. Very pronounced « saddles » are apparent on the high rail of a curve about 5 feet in advance of the joints on the low rail.

(d) « *Facts observed in connection with rails with undulatory wear that have been reversed.* »

Practically no information available concerning the effect of reversing or transposing corrugated or « saddled » rails. New South Wales has carried

out tests of re-using corrugated rails on sharp curves with good results. These rails were corrugated to depths of 0.015 inches and relaid in a single line on curves of 16-chains and 20-chains radius, some five (5) years ago and today the corrugations have almost entirely disappeared.

(e) « *Evolution of undulatory wear that started with accidental or artificial damage.* »

No information available, except New South Wales, concerning grinding and heat treatment. Grinding of these rails was carried out just below the original troughs and heat treated. The corrugation re-appeared in identical spots where original peaks existed, after three (3) months in service and has rapidly increased since.

Welding F.B. or Thermit has caused distinct cupping either side of weld on rails after some considerable service. This effect is very noticeable in steam tunnels after eighteen (18) months. This effect is attributed to the altered metallographic structure due to welding. Further undulations developing from these suppings are negligible.

QUESTION 6.

Formation and evolution of undulatory wear :

(a) *Time between the laying of the track and the appearance of the first sign of undulatory wear;*

(b) *The pattern of the undulatory wear from its beginning and its growth;*

(c) *Whether the existence of a joint has any effect on the regularity of undulatory wear waves;*

(d) *Facts observed in connection with rails with undulatory wear that have been reversed;*

(e) *Evolution of undulatory wear that started with accidental or artificial damage.*

In particular, phenomena observed with welded rails (electric, aluminothermic welding, etc., welded rails of different metallic composition).

* * *

INDIA.

(*a*) No data available — verbal evidence, however, shows corrugation appears soon after laying.

(*b*) No record to show the growth of wear with time or traffic available.

(*c*) Has no effect on the development.

(*d*) Data not available.

(*e*) No case on record.

VICTORIA.

(*a*) Type A. — « Roarers. » — No definite figures, but three (3) rails developed incipient corrugations after three months in service.

Type B. — « Saddles. » — About twelve (12) months on one particular curve.

(*b*) Type A. — « Roarers. » — Commences with formation of intermittent martensitic bands. Increased by corrosion in troughs and cold working of softer area between these bands.
Type B. — « Saddles. » — No information available.

(*c*) Type A. — « Roarers. » — Dipped joint or « high » welded joint causes corrugation to die away for approximately 2 to 4 feet adjacent to the joint. Welded joint or fishplate joint, which is in good alignment, has no effect on regularity of corrugation.

Type B. — « Saddles. » — Welded and fishplated joints in good condition do not affect this type of corrugation.

(*d*) Types A and B. — No information.

(*e*) Types A and B. — No experience.

JAPAN.

(*a*) Appreciably noticeable within first twelve (12) months.

(*b*) Rails in undersea tunnel on concrete bed, six (6) months after laying showed gentle wear 1 m wave length 0.5 mm (0.020 inches) deep, after two (2) years seven (7) months wave length 20 cm (8 inches) to 30 cm (12 inches) and depth of .3 mm to .5 mm (0.010 to 0.020 inches).

(*c*) and (*d*) In tunnel above undulatory wear started from a rail joint. Joint was then staggered and different pattern of corrugation commenced.

(*e*) No comment.

BRITISH RAILWAYS.

Definite comment only on 6 (*c*) which reads :

Corrugation has been observed to start at the running end of a rail caused by the influence of the joint. Other incidents where corrugation commenced in mid-rail. There are also a large number of instances of wheel burns on rails where the vibrations set up by wheels passing over these depressions have not led to formation of corrugations.

EAST AFRICAN RAILWAYS.

(*a*) Varies — no accurate records.

(*b*) No information.

(*c*) No information.

(*d*) Little or no effect.

(*e*) No information.

SWEDEN.

(*a*) Corrugations appeared when the rails were being laid.

(*b*) Amplitude of the wave decreasing during the fourteen (14) years in track. More rapid decrease on curves.

(*c*) Joints have a visible effect on the corrugations which in most cases have disappeared completely on the section of rail over the fishplates.

(*d*) No experience.

(*e*) No comments.

NEW ZEALAND.

No comment.

SOUTH AFRICAN RAILWAYS.

(*a*) Three (3) months or earlier.

(*b*) Reply refers more to saddled rails than to washboard corrugations. Troughs develop in the second half of the sleeper spacing in direction of traffic on double lines. The crests are found in the first quarter of the sleeper spacing on double lines (Down hill on single track). Mushrooming towards outside on outer rail — generally very heavy on inner rail.

(*c*) Particularly deep just beyond the rail joint in the direction of traffic. No irregularity in the change of depth along the rails — « Saddled types ».

(*d*) Rails are not reversed.

(*e*) Welding of joints gave some improvement.

ASSOCIATED AMERICAN RAILROADS.

(*a*) No information.

(*b*) No information.

(*c*) Only record was where undulatory wear was most noticeable in the vicinity of joints and the leaving quarter of the rails — straight track, passenger traffic — Rails on the curve were not corrugated.

(*d*) Transposing corrugated rails has a tendency to throw the wear on a different portion of the rail and may result in some improvement. Rails transposed from high side to low side of curves appear to be particularly subject to corrugation, due probably to heavy loading on low rail and narrow head.

(*e*) No information.

EIRE.

(*a*) No information.

(*b*) No information.

(*c*) Joints appear to have no effect, but in

many cases corrugations begin or end at a joint.

(*d*) No information.

(*e*) Corrugations not associated with accidental or artificial damage.

NEW SOUTH WALES.

(*a*) Type A. — « Roarers » — vary three to twelve months, depending on position in track — straight, flat curve or grade.

Type B. — « Saddles. » — Long — three to six months, depending on grade of track and hardness of rails. Low carbon rails were removed from the track after fifteen (15) months.

Type C. — « Saddles. » — Short — concrete bed — visible after two (2) months.

(*b*) Type A. — « Roarers » — long shiny narrow spots — long centre head of rail then developing into scollop formation, finally developing to transverse ridges highly polished and hard with tarnished coloured depressions between.

Type B. — Indicated by high spots at long varying pitch with slight overflow of metal along outside face of rail between these high spots, overflow extends with growth. Texture of surface is uniform in appearance, with traces of the effect of wheel slip.

Type C. — Indicated by the rough dull surface — appears intermittently in small patches along top surface of rail.

(*c*) Type A. — No definite pattern.

Type B. — Fishjoints affect this type of wear. The depressions are invariably deeper on receiving side of joint. Cross joints, the saddle are very pronounced, about 5-foot lead to joint on opposite rails — due to oscillation of electric vehicles.

Type C. — Yes, but with no definite pattern particularly noticeable on low rail.

(*d*) Type A. — Corrugated rails with depth 0.015 inches recovered from straight track and re-used on curved track under 20 chains (4° 20′) radius. The corrugations had entirely disappeared ater five (5) years in service. Reversing of rails — no information.

Type B. — No information.

Type C. — No information.

(*e*) Type A. — Corrugated rails ground and heat treated — the corrugations reappeared in identical spots, where original peaks existed, in three (3) months and rapidly increased.

Grinding of these rails was carried out just below the original troughs.

In relation to welding electric flash butt and thermit, distinct cupping is evident either side of weld on rails after considerable service, particularly noticeable in tunnels after eighteen (18) months.

LONDON TRANSPORT.

(*a*) Type A. — Variable between a few days and twenty (20) months.

Type B. — A few weeks.

(*b*) Type A. — Irregular unevenness develops slowly by increasing amplitude and adjustment of a more regular profile.

Type B. — From the insertion the pitch of battering is not altered, but depths increase.

(*c*) Type A. — Joints appear capable of starting a fresh series of waves (i.e. of producing a discontinuity of the pitch).

(*d*) Type A. — No observations.

Type B. — No observations.

(*e*) No observations.

It is noticeable that the absence of joints in long welded rails reduce the liability to battering.

* * *

QUESTION 7.

Have you compared rails having undulatory wear with those which have none, taking as factors for such comparison :

(a) « *The wear of the head.* »

Very little information regarding this question — Eire reports headwear appears to be similar to uncorrugated rails. In New South Wales it has been observed that low carbon (soft) rails are less prone to corrugation (roaring) than harder rails.

(b) « *The age of the rails.* »

General opinion is that age of rail has no bearing on the issue.

(c) « *The frequency of broken rails.* »

Victoria and New South Wales are the only Systems with definite views on this question. Both have experienced trouble with fractures attributed to the « saddle » type of undulatory wear. New South Wales is concerned with fracture occurring along the web, particularly along the top and bottom fillets. Failures of this type are more frequent over concrete road bed under multiple unit electric rolling stock.

Question 7. — Have you compared rails having undulatory wear with those which have none, taking as factors for such a comparison :

(*a*) the wear of the head;

(*b*) the age of the rails;

(*c*) the frequency of broken rails.

INDIA.

No data available — although of the opinion that age of rail has little to do with the initiation of corrugations, they appear early in life of rail and tend to disappear after some time when adjacent corrugations meet each other.

VICTORIA.

(*a*) No.

(*b*) No.

(*c*) « Roarer » type of corrugation. Liability of rail failure is not influenced by this type of corrugation.

« Saddle » type of corrugations. Rails affected by this corrugation have a higher incidence of failure, due principally to flow metal cracks.

JAPAN.

No comment.

BRITISH RAILWAYS.

No comment.

EAST AFRICAN RAILWAYS.

« No » to all three questions.

SWEDEN.

No observations on (*a*) and (*b*).

(*c*) None broken.

NEW ZEALAND.

No data available.

SOUTH AFRICAN RAILWAYS.

No data available.

ASSOCIATED AMERICAN RAILROADS.

No information re' (*a*) and (*c*).

(*b*) One rolling at one head of rail in 1942 found to have corrugations when inspected at the mill, due to chattering of the rolls. When placed in the track, the rail was ground immediately.

The corrugations re-appeared in two (2) years — 40 miles per hour territory.

EIRE.

(*a*) Head wear appears to be similar to uncorrugated rails.

(*b*) Corrugated rails are principally fairly old, but this may be due to the time required for this development.

(*c*) Breakages unusual, but this is probably due to the very small proportion of rails on the System, which are corrugated.

NEW SOUTH WALES.

No comparisons taken, but observations disclosed that rails with low carbon and manganese are less prone to corrugate than the harder rails.

« Saddled » rails on hard concrete bed are very prone to fracture particularly in the web.

LONDON TRANSPORT.

No comparisons have been made.

* * *

Summary of Section II.

INFLUENCE OF THE COMPONENT ELEMENTS OF THE TRACK UPON UNDULATORY WEAR.

The composition and hardness of rails is a factor, which can influence the tendency to corrugations. Opinions are expressed that rails, high in carbon, with high hardness value, are more prone to the « roaring » type of corrugation than soft rails. British and New Zealand Systems have only experienced this type of corrugation when rails have been surfaced hardened by « Sorbitising ». Under multiple unit electric traction where « saddling » of rails occur, the incidence of undulatory wear is greater where rails are in the lower carbon range.

The processing of rails such as rolling, straightening, etc., is not usually regarded as a contributing factor toward corrugation. This also applies to the weight, length and design of section of the rail. Corrugations are observed to occur in practically all weights and lengths of rails.

South Africa has made reference to sectional properties and has reported tests, which show that increase in moment of inertia (generally accompanied by increase in weight) decreases the development of corrugations. This evidently refers to the « saddle » type of undulatory wear with which South Africa is mainly concerned. Opinion has been expressed that with welding of rails some benefit has been derived, but evidence submitted does not support this. The use of check rails and the widening of gauge does not appear to give any benefit.

No conclusive information has been submitted regarding the influence of sleepers upon undulatory wear. Two Systems, which have commented on the question are in accord that corrugations are more pronounced over timber sleepers than those of steel or concrete. Victoria has reported carrying out tests by placing steel sleepers under a short section of track, which was severely corrugated, and has observed that the corrugations tend to die out over these sleepers. No mention is made of the duration of tests.

South African Railways, who are mainly interested in the « Saddle » type of undulatory wear has observed that a decrease in the development of undulatory wear is evident where sleeper spacing is decreased. The minimum spacing 56 cm (22 inches) is limited by the need for maintenance space.

Practically no investigation has been carried out by any of the System regarding the influence of ballasting on undulatory wear. Crushed stone and gravel is mainly used, sizes varying between 1 1/2 to 2 1/2 inches (38-64 mm) with depths below sleepers 6 to 9 inches (15-23 cm).

Very little evidence has been advanced regarding the influence of road bed upon undulatory wear. Reports have been received, however, that rails laid on timber sleepers in concrete under multiple-unit electric traction, develop the « saddle » type of undulatory wear more readily than on the conventional ballasted track. This condition has also been observed through level crossings, where rigidly supported.

Fishplates and type of joint appear to have no influence upon undulatory wear. Tests have been carried out with square and staggered rail joints, but no change in pattern has been observed.

Section II.

INFLUENCE OF THE COMPONENT ELEMENTS OF THE TRACK UPON UNDULATORY WEAR.

QUESTION A. — 1. *The rail.*

Is there any proof that the composition and method of fabricating the rails may influence the tendency to undulatory wear?

(a) « *Composition of the steel, its hardness.* »

India, Victoria, Sweden, American Railroads and Eire report no definite information — British and New Zealand Systems have experienced « roaring » corrugations with « sorbitic » rail. Other Systems are in accord that high carbon, hard rails, are more prone to « roaring » type corrugations than soft rails. Whereas soft rails under multiple-unit electric traction « saddle » vary rapidly.

(b) « *Size of the ingot.* »

None of the Systems give any information regarding any influence the size of ingot may have on undulatory wear.

(c) « *Vibrations during rolling and irregular, non uniform cooling.* »

Practically no information except from India and Sweden, who report that vibration set up during rolling operations contributes to « roaring » type corrugations. Very little proof has been submitted from these two countries in this regard.

(d) « *Method used in straightening the rails after rolling.* »

No information submitted.

(e) « *Observations on segregation.* »

No information.

INDIA.

(*a*) No information.

(*b*) No information.

(*c*) On some newly rolled rails observed presence of waves of pitch ranging 2 to 54 inches up to 25 miles.

(*d*) No information.

(*e*) No information.

VICTORIA.

(*a*) Type A (Roarers). — No relationship observed.

Type B (Saddles). — No relationship observed.

(*b*) Type B (Saddles). — No relationship observed.

(*c*) Type B (Saddles). — No relationship observed.

(*d*) Type B (Saddles). — No relationship observed.

(*e*) Type B (Saddles). — No relationship observed.

JAPAN.

As a result of test mileage where one rail corrugated and an adjacent rail did not, it was considered corrugation occurred because of difference in properties of the two rails.

No sign of decarbonisation observed in the non-corrugated rail, whereas it was in the side of head of the corrugated rail.

Deformation of crystal grains on surface of rail head, in contact with wheel tread observed in corrugated and non-corrugated rail. Size crystal grains was small at the ridge and large at the grooves.

Corrugated rail carbon content . 0.65 %
Non-corrugated rail carbon content 0.40 %
Hardness top of corrugated rail greater than the one not corrugated.

BRITISH RAILWAYS.

« Sorbitised » rails prone to corrugate.

EAST AFRICAN RAILWAYS.

(*a*) to (*e*) No information.

SWEDEN.

Manufacturer of the rails in question admitted that corrugation was due to vibrations during rolling, and as corrugations

were observed immediately after the first trains had passed over them, corrugations were caused from the method of fabrication.

(*a*) Med. Mang. (C — .5 % to .6 % an .9 % to 1.10 %). Tensile 75 kg/sq. mm — hardness 200 H.B.

(*b*) (*c*) (*d*) (*e*) No comments.

NEW ZEALAND.

(*a*) Yes — British rails treated by Sandberg (sorbitic) process give considerable trouble due to undulatory wear.

(*b*) (*c*) (*d*) (*e*) No information.

SOUTH AFRICAN RAILWAYS.

Yes.

(*a*) Stronger and harder rails corrugated and wear more slowly than softer rails, particularly the difference between Martin and Thomas steel rails, the latter having a considerably lower hardness.

(*b*) No information.

(*c*) No information.

(*d*) Gag straightening may leave initial corrugations. Should only have influence if they conform more or less to sleeper spacings.

(*e*) Segregations make rail weaker, hence corrugations should be worse.

ASSOCIATED AMERICAN RAILROADS.

(*a*) to (*e*) No proof available. Locations recorded where undulatory wear has repeatedly occurred in rails of different rollings.

EIRE.

(*a*) to (*e*) No difference between rails as regards tendency to corrugate.

NEW SOUTH WALES.

(*a*) Rails containing high carbon and manganese contribute to undulatory effect more so than low carbon rails. Soft rails under electric multiple-unit « saddle » vary readily.

(*b*) No knowledge.

(*c*) No verification of this fact.

(*d*) No knowledge.

(*e*) Undulatory rails sent for undulatory wear tests disclose no segregation.

LONDON TRANSPORT.

(*a*) Harder steels have more resistance, but no steel has been found proof against corrugations or batter.

(*b*) No observations.

(*c*) and (*d*) New rails with slight unevenness left from the rolling are thought to be more liable to corrugations.

(*e*) No observations.

* * *

QUESTION A. — 2. *Other Factors.*

(a) *Weight and length of the rails, limits of elasticity, moment of inertia, form of the profile, and in particular the design (width, curvature, radii) of the running surface;*

(b) *Use of welded rails;*

(c) *Use of check rails;*

(d) *Widening of the gauge.*

Information supplied by the various Systems on these questions do not supply anything conclusive regarding the influence of the factors covered by section (*a*) to (*d*) upon undulatory wear. It is observed that undulatory wear does occur on practically all weight of rails, also on any lengths. South Africa is the only System which makes any reference to the Sectional and physical properties having any influence. They report that tests show that increase in moment of inertia (generally accompanied by increase in weight) decreases the development of corrugations.

This appears to apply to the « saddle »

type of undulatory wear, which is the only type which concerns that System.

INDIA.

(*a*) to (*d*) None of these elements by itself can be identified as having influenced corrugations.

VICTORIA.

(*a*) Type A. — « Roarers » / Type B. — « Electric-Traction » } No relationship observed.

(*b*) No relationship observed.

(*c*) and (*d*) Type A. — « Roarers » — check rails and gauge widening only to sharp curves, which are not affected by this type of corrugation.
Type B. — « Electric-traction. » — No information.
Type C. — No influence.

JAPAN.

(*a*) Nothing conclusive.

(*b*) (*c*) (*d*) No comment.

BRITISH RAILWAYS.

No comment.

EAST AFRICAN RAILWAYS.

(*a*) Rails affected are 80-lb. BS section 40-feet long.

(*b*) (*c*) Nil.

(*d*) Allowable gauge widening on curves 1° to 4°, nil; 5° to 8°, 3/8 inch maximum; 9° to 16°, 3/4 inch maximum.

SWEDEN.

(*a*) Weight 41.18 kg/m length 20 m.

(*b*) (*c*) (*d*) No comments.

NEW ZEALAND.

(*a*) Undulatory wear found on all weights of rails — 56-lb. to 100-lb./yard, on any type of formation. Rails generally flat bottom medium manganese. B.S.S. No. 11 spec. Lengths 42 feet generally.

(*b*) Flash butt welded rails 252 feet used in main line. — No comments re' effect on undulatory rails.

(*c*) (*d*) No comments.

SOUTH AFRICAN RAILWAYS.

(*a*) Tests show increase in moment of inertia decreases the development of corrugations. The lateral moment of inertia is particularly important.

(*b*) Welding of rails is beneficial to a small extent, as it eliminates joints. Welding of rails has not been possible due to sharp curves.

(*c*) Check rails give some reduction to the depth of corrugation, but only if they have no joints as these lead to very deep corrugations. Long welded check rails are being tried where possible.

(*d*) Suggests tight gauge retards corrugation and wear.

ASSOCIATED AMERICAN RAILROADS.

No information.

EIRE.

(*a*) to (*d*) Factors mentioned appear to have no bearing on the incidence of corrugations. Corrugations never occur before some head wear and change of profile has taken place.

NEW SOUTH WALES.

(*a*) No data on hand — found on practically all weights of rails 80 to 107-lb./yard. Lengths single 40-foot to all lengths of welded rails.

(*b*) Incidence rate of corrugation on welded rails is no more than on loose short rails.

(*c*) No information.

(*d*) No apparent influence.

LONDON TRANSPORT.

(*a*) and (*b*) No observations.

(*c*) No information on corrugations, but the installation of check rails has reduced battering.

(*d*) No observations.

* * *

QUESTION B. — *The sleepers.*

(a) *Shape;*

(b) *Material;*

(c) *Spacing.*

Practically no conclusive information has been submitted regarding the influence of sleepers upon undulatory wear. Victoria and Japan are the only two Systems which have commented on the question and both are in accord that corrugations are more pronounced over timber sleepers than those of concrete and steel.

Victoria reported carrying out a test, by placing heavy steel sleepers under a short section of track severely corrugated. It was observed that the corrugation tends to die out over these steel sleepers. No mention is made of duration of test.

Spacing of sleepers varies from 22 to 32 inches.

INDIA.

(*a*) (*b*) (*c*) None of these elements by itself can be identified as having influenced corrugations.

VICTORIA.

(*a*) No experience.

(*b*) Type A. — « Roaring corrugation » — on severely corrugated track wear dies out over a short test section of heavy channel steel sleepers.

Type B. — « Electric-traction ». — No experience.

(*c*) Type A. — « Roarers. » — No relationship observed.

Type B. — « Electric-traction. » — No relationship observed.

JAPAN.

(*a*) No comments.

(*b*) Corrugation greatest on timber sleepers and absence of tie plates has little to do with the frequency of the occurrence of the corrugation. Concrete sleepers and bridge transoms the least.

(*c*) Frequency of occurrence seems to be almost independent of the spacing.

BRITISH RAILWAYS.

No comment.

EAST AFRICAN RAILWAYS.

Types of sleepers only given.

(*a*) Hollow section.

(*b*) Steel.

(*c*) 2-feet 8 inches maximum.

SWEDEN.

Redwood sleepers only used. Size 210 × 160 × 2 600 mm.

Sleeper spacing as 800 mm.

No other comment.

NEW ZEALAND.

Australian hardwood 8 inches × 5 inches, 7-feet long, also 9 inches × 4 1/2 inches × 7-feet long, 2-feet 2 inches to 2-feet 6 inches centres generally.

No other comment.

SOUTH AFRICAN RAILWAYS.

(*a*) Not investigated.

(*b*) Steel sleepers on steam line, timber on electrified line. (H.W. and Soft wood) 25.5 × 13 × 213 cm. Electrified lines.

(*c*) Reduced spacing decreases development of corrugations. Spacing 56 cm minimum.

ASSOCIATED AMERICAN RAILROADS.

No information.

EIRE.

Corrugated rails occur on all types of timber sleepers; on which the spacing is all more or less similar.

NEW SOUTH WALES.

No investigation carried out.

(*a*) 9 inches × 4 1/2 inches × 8-feet long.

(*b*) Hardwood.

(*c*) 2-foot 1 inch centres.

LONDON TRANSPORT.

(*a*) and (*b*) No observations.

(*c*) Type A. — Appear to have shorter pitch on longitudinal timber track than with cross sleepers and, in general, appear more severe on rigid track.

Type B. — Appear to be synchronised by the sleeper space.

QUESTION C. — *The Ballast.*

(a) *Material;*

(b) *Size;*

(c) *Thickness of the layer of ballast.*

Practically no investigations have been carried out by the various Systems regarding the influence of ballast on undulatory wear.

Japan has reported incidence of corrugations very high on concrete bed, next highest on crushed stone, followed by screened gravel, unscreened gravel much less and slag very small. They also observed that the greater depth of ballast the more frequent undulatory wear occurs.

Other Systems report crushed stone and gravel, size varying between 1 1/2 inches to 2 1/2 inches. The depth of ballast below sleepers varies from 6 inches to 9 inches.

* * *

INDIA.

(*a*), (*b*), (*c*) None of these elements by itself can be identified as having influenced corrugation.

VICTORIA.

(*a*), (*b*), (*c*) No relationship observed.

JAPAN.

(*a*) Incidence of corrugation very high on concrete road bed. Next highest on crushed stone, followed by screened gravel, unschreened gravel much less and slag very small amount.

(*b*) Effect of size of ballast is not known.

(*c*) Greater depth of ballast the more frequently undulatory wear occurs.

BRITISH RAILWAYS.

No comments.

EAST AFRICAN RAILWAYS.

Ballast, stone 2 1/2 inches (6.3 cm) maximum 11 inches (28 cm) deep nominal.

No other comments.

SWEDEN.

The ballast is sand and gravel and has a depth of 50-60 cm (20-24 inches).

No other comments.

NEW ZEALAND.

No comments.

Crushed stone or gravel 1 1/2 inches; 9 inches deep under sleeper.

SOUTH AFRICAN RAILWAYS.

Effect not investigated.

(*a*) Ballast used crushed stone.

(*b*) 6.3 cm (2 1/2 inches).

(*c*) 34 cm (13 inches) deep to top of sleeper at centre of track.

ASSOCIATED AMERICAN RAILROADS.

No information.

EIRE.

They occur on stone or gravel ballast.

NEW SOUTH WALES.

No investigation carried out.

(*a*) Ballast on main line.

(*b*) 1 1/2 inches (3.8 cm).

(*c*) 6 inches minimum below sleepers.

LONDON TRANSPORT.

(*a*)
(*b*) } No observations.
(*c*)

* * *

QUESTION D. — *The Bed.*

Very little evidence has been submitted regarding the influence of road bed upon undulatory wear. Victoria reports that the « Roaring » types of corrugation are not usually affected by rigid bed. Whereas with the « saddled » type of undulatory wear, the rails rigidly supported in level crossings, etc., are very much affected. New South Wales and India have not found any conclusive features that road bed formation is a contributing factor towards the « roaring » type of corrugations. It has been found, however, that rails laid on timber sleepers in concrete, under multiple-unit electric traction develop the « saddle » type of undulatory wear more readily than on conventional ballasted track. South African Railways, who seem to be more troubled with the « saddled » type of undulatory wear, also concurs with this observation.

British Railways report certain places in the track are known to be liable to cause corrugations, since successive supplies of rails have corrugated when laid in these positions. It is considered that the cause may lie in the geological formation beneath the ballast.

INDIA.

This element by itself cannot be identified as having influenced corrugations.

VICTORIA.

Type A. — « Roaring corrugation. » — Rigid beds not usually affected by this type of corrugation.

Type B. — « Saddles. » — The rails rigidly supported in level crossings, etc., are liable to this form of wear.

JAPAN.

No comment.

BRITISH RAILWAYS.

Consider geological formation beneath ballast may be main cause as certain places in the track are known to cause corrugation. Successive supplies of rails corrugating in the same track positions.

EAST AFRICAN RAILWAYS.

Decomposed clay shale in worst parts near the Coast.

No other comments.

SWEDEN.

Bed good quality and well drained.

No other comments.

NEW ZEALAND.

No comment.

SOUTH AFRICAN RAILWAYS.

Corrugations seem more numerous on harder bed in rock cuttings. Corrugated curves are located in mountainous country. (This mainly concerns « saddle » type undulations.)

ASSOCIATED AMERICAN RAILROADS.

No information.

EIRE.

They occur on soft or hard formation.

NEW SOUTH WALES.

Road bed formation has not been found a contributing factor to the « roarer » type corrugations. Rails on concrete bed under multiple-unit electric traction on sharp curve, « saddle » more readily than over ballasted track.

LONDON TRANSPORT.

No observations.

* * *

QUESTION E. — *The Joint.*

(a) *Supported;*
(b) *Overhanging;*
(c) *Square or staggered.*

Practically no information is derived from replies to the question of type of joints, if they have any influence upon undulatory wear. New South Wales, Eire and South Africa have reported that with square or staggered joints, there is no noticeable change in undulatory pattern observed.

INDIA.

(a) (b) (c) None of these elements by itself can be identified as having influenced corrugations.

VICTORIA.

(a) (b) (c) No relationship observed.

JAPAN.

No comment.

BRITISH RAILWAYS.

No comment.

EAST AFRICAN RAILWAYS.

(a) None.
(b) Sleeper spacing 9 inches (23 cm) —
(c) square on straight, staggered on curves.

SWEDEN.

(a) (b) Joints supported with one sleeper under the gap between the rails and one sleeper under each end of the fishplates.
(c) No comment.

NEW ZEALAND.

(a) No supported joints.
(b) Overhanging standard.
(c) Square joints.

SOUTH AFRICAN RAILWAYS.

(a) Not investigated.
(b) Overhanging joints.
(c) Joints are square; staggering gave no improvement.

ASSOCIATED AMERICAN RAILROADS.

(a) (b) (c) No information.

EIRE.

Corrugations occur with supported, overhanging, square or staggered joints.

NEW SOUTH WALES.

(a) Some in service.
(b) Overhanging now in use. No investigation in respect to undulatory wear.
(c) Both square and staggered in use. No noticeable change of undulatory pattern observed.

LONDON TRANSPORT.

No observations.

* * *

QUESTION F. — *Fishplates.*

Types.

No information has been supplied concerning fishplates being identified as having influenced corrugations.

INDIA.

This element by itself cannot be identified as having influenced corrugations.

VICTORIA.

No relationship observed.

JAPAN.

No comment.

BRITISH RAILWAYS.

No comment.

EAST AFRICAN RAILWAYS.

2 hole and 4 hole standard plate. 80-lb. rail B.S.

SWEDEN.

Angle fishplates used. 915 mm length.

NEW ZEALAND.

4 hole fishplates.

SOUTH AFRICAN RAILWAYS.

Not investigated.

ASSOCIATED AMERICAN RAILROADS.

No information.

EIRE.

Occur on different type of fishplates without any apparent difference.

NEW SOUTH WALES.

Both angle and strap plates are in use — no noticeable change in undulatory pattern observed.

LONDON TRANSPORT.

No observations.

* * *

Summary of Section III.

INFLUENCE OF FACTORS EXTRANEOUS TO THE TRACK.

Particulars concerning types of rolling stock and its construction (Question A) reported by South Africa, London Transport, New South Wales and Victoria are shown in Table 1. The information supplied by these authorities appears to be too varied to be of much assistance in assessing the extent of influence on undulatory wear.

It is generally expressed that the growth of both types of undulatory wear is affected by the frequency of service. Some doubt exists, however, regarding the effect of speed on the growth of undulatory wear. India, Japan, London Transport and New South Wales affirm this fact, whilst Victoria, East Africa and Eire are of the opinion that speed has no effect whatever.

Most countries have reported that humidity and damp atmospheric conditions are influencing factors in the growth of corrugations. This is particularly noticeable in or at the entrances to tunnels, where steam traction predominates.

Very little information has been submitted by any of the Authorities regarding influence of combinations due to factors such as type of traction, type of drive, axle loads, etc., but it is generally acknowledged that these do play very important parts in the formation of the types of undulatory wear. The « roarer » type of wear is usually associated with steam traction and the corrugation develops more rapidly on track where the proportion of lightly loaded goods vehicles is high compared with those with full tonnage loads. With the « saddle » type no difference is found as this type is normally associated with multiple unit electric passenger traction with more or less uniformity of loadings.

Corrugations of the « roaring » type are observed to vary on adjoining track, which can be attributed to the proportion of light and heavily loaded vehicles on each track.

No appreciable difference is observed of « saddle » type of wear on adjoining Up and Down tracks, except on grades.

« Roaring » type undulatory wear is affected where regular braking is applied. Such braking minimises growth and this is most apparent through Station platform roads, even where only a few trains stop each day. « Saddle » type of wear also dies out through Stations where on straights, but braking on curve tends to promote this type of undulatory wear.

On single line, where « roarer » type of corrugation occurs the pattern is not so clearly defined as in the case of one direction track.

The opinion expressed by the various Authorities regarding the effect of gradient on undulatory wear, differs to the extent that no conclusive finding can be reached. On the New South Wales System « roarer » type wear on straight single track is similar on level and flat gradings, but varies on double track. Where gradients are steep and long, corrugations do not occur to the same extent, probably due to braking and slipping. With « Saddle » type of undulatory wear, gradient on curves does

have an effect and it is apparent that growth is influenced by both acceleration and braking. In New South Wales, the effect is most pronounced on the low rails of curves when on a rising grade.

QUESTION A.

Factors concerning the type of rolling stock and its construction.

(a) *Type of traction (steam, electric, motor units);*
(b) *Type of drive (direct, gears, rods);*
(c) *Mass and power of the motors;*
(d) *Axle journals (bearings, roller bearings, dimensions, diameter and length);*
(e) *Diameter and profile of the tyres;*
(f) *Type of and material used for the brake shoes;*
(g) *Type of shock absorbers and vibration dampers;*
(h) *Arrangement and spacing of the driving and carrying wheels;*
(i) *Weight and distribution of the loads on the axles;*
(j) *Effect of loaded and empty vehicles;*
(k) *Ratio of the non-suspended weight to the total weight of the vehicles.*

INDIA.

(*a*) to (*k*) No information to say how factors mentioned affect undulatory wear.

VICTORIA.

Type « A ». — « Roarer type » — corrugations occur on lines with goods traffic only, as well as normal main lines. It is not possible to relate the type of rolling stock which have an influence on formation of this type of corrugation.

Type « B ». — With electric traction — electric multiple-unit passenger coaches. Details of rolling stock associated with

Type « B » undulatory wear are shown in Tabulation 1.

JAPAN.

(*a*) Survey 1957 disclosed that undulatory wear seemed to occur more where electric cars are operating.

Electric Traction. — Undulatory wear 40 to 50 cm pitch 1.5 mm depth.

Impact with electric cars was greatest, electric locomotives and empty freight cars next and that of loaded freight cars, especially 2 axle was the smallest. Similar surveys over steam track — 30 cm pitch, depth 1 to 2 mm disclosed impact was great with locomotive passenger cars and light axle loaded freight cars, whereas it is small with freight cars of heavy axle loads.

Locomotives and wheels of small axle loads cause oscillation of a large amplitude. Wheels of large axle loads cause oscillation of small amplitude. Whereas both passenger trains and electric multiple units cause oscillation of large amplitude.

(*b*), (*c*), (*d*) No comments.

(*e*) Is affected by wheel profile with 1 in 10 slope. Undulatory wear occurs little on curves and for most part and straights.

Horizontal wheel tread wear is confined to curves, mainly to inside rail.

(*f*) No comments

(*g*) If vibration damper is installed along with the spring, will greatly retard undulatory wear.

(*h*) Observed short wheel base vehicle, such as driving wheels of locomotives aggravate undulatory wear.

(*i*) No comments.

(*j*) Impact greater with empty cars than with loaded cars with great axle loads — 2 axle freight cars with great axle load is the least.

(*k*) Rolling stock, whose non-suspended weight is great. cause a heavy impact.

TABULATIO

Influence of factors extraneous to the track. F

Railway	*(a)* Type of traction	*(b)* Type of drive viz. direct, gears, et
South African	*Steam :* 20 km Single track *Electric :* 250 km Double and single track	*Steam :* Rod drive *Electric :* Hose suspended with single reduction gears
London Transport	*Electric :* Multiple unit stock	Geared
Victoria (Australia)	*Steam :* No information *Electric :* Multiple unit stock	*Steam :* No information *Electric :* Gears
New South Wales (Australia)	*Steam :* 38 Class *Steam :* 60 Class *Electric :* Multiple units 4 motors equipment Suburban and interurban *Electric :* Multiple unit 2 motors equipment	*Steam :* 38 Class Rod *Steam :* 60 Class Rod *Electric :* 4 motors gear and pinion *Electric :* 2 motors — gear and pinion

TION III.

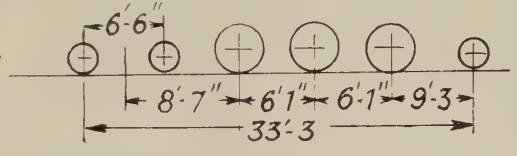
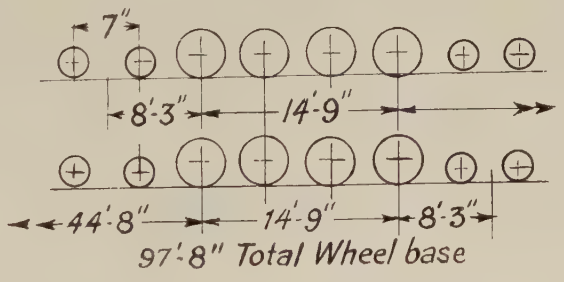
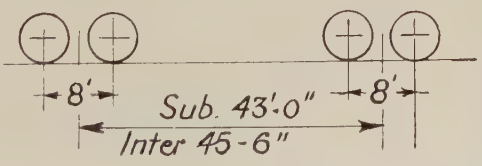
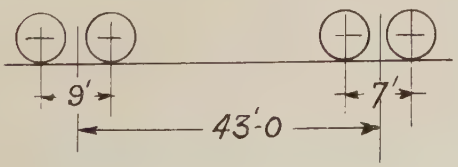
rning the type of rolling stock and its construction.

(c) Mass and power of the motors	*(d)* Axle journals, bearings - diameter and length
eam : Class 15 AR tractive force (75 %) 15 370 kg ass GMAM Garratt force (75 %) 27 540 kg *lectric :* Class 1 E Mass 4 000 kg - 300 HP - 4 motors Class 5 E Mass 4 230 kg - 500 HP - 4 motors Class 4 E Mass 5 340 kg - 505 HP - 6 motors	*Steam :* Class 15 AR Leading bogie : 138 × 267 mm » Coupled axle : 216 × 267 mm » Coupled driver : 229 × 267 mm » Trailing bogie : 152 × 311 mm » GMAM Garrat - Roller bearings *Electric :* Class 1 E 140 × 279 mm and roller bearings Class 5 E Roller bearings Class 4 E Roller bearings
ube stock : 3 200 lb. - 80 HP urface stock : 3 700 lb. - 80 HP	Roller bearings. Tube stock 5 1/2″
team : No information *lectric :* Weight of motor 2-ton 12-cwt. Power — 146 HP (1 hour)	*Steam :* No information *Electric :* 9″ × 5 1/2″ diameter — white metal
— — *Electric :* 4 motors — weight 2-ton per motor — 1 hour rating 190 HP — continuous rating 160 HP — 4 motor/car *Electric :* 2 motors — weight 2-ton per motor — 1 hour rating 350 HP — 2 motors per car	*Steam :* 38 Class : Bogie 160 mm diameter Driving 10 1/2″ diameter Leading and trailing 9 3/4″ diameter Trailing truck 160 mm diameter Roller bearing *Steam :* 60 Class : Bogie 180 mm diameter Coupled wheels 225 mm diameter Roller bearing *Electric :* 4 motors — 130 mm roller bearings *Electric :* 2 motors — 5 1/2″ diameter × 11″ long plain bearings

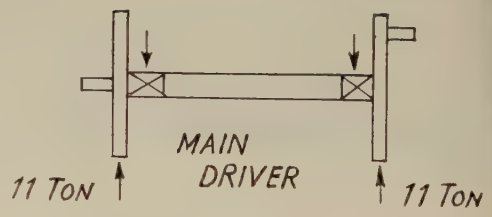
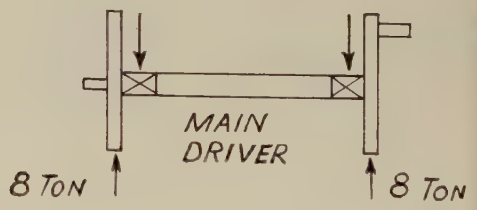
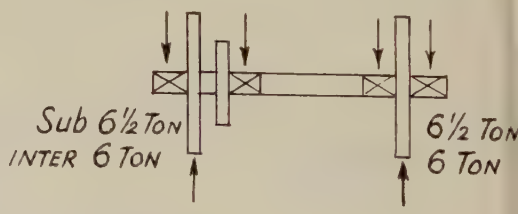
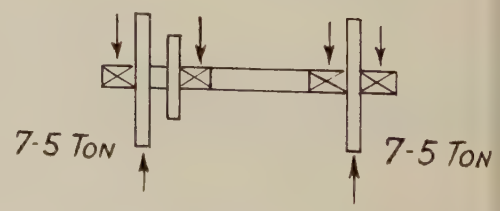
Influence of factors extraneous to the track. F

Railway	*(e)* Diameter and profile of the tyres	*(f)* Type of material used for brake sho
South African	Standard profile 1 in 20 Tread diameter *Steam :* Class 15 AR Leading bogie : 724 mm Coupled wheel : 1 448 mm Trailing bogie : 838 mm Class GMAM Outer bogie : 762 mm (Garratts) Coupled wheels : 1 372 mm Inner bogies : 762 mm *Electric :* Class 1 E All wheels : 1 016 mm Class 5 E All wheels : 1 016 mm Class 4 E Truck wheels : 762 mm Driving wheels : 1 196 mm	Brakes are clasp type cast iron block bearing on coupled or driving whee only *Steam :* Class 15 AR has steam brakes engine Vacuum brakes on tender Class GMAM Garratts and electric engines have Vacuum brake Electric also have regenerative braki
London Transport	Tube stock : 31″ Surface stock : 36″	Non-metallic brake block held in brake head by key
Victoria (Australia)	*Steam :* No information *Electric :* Diameter : 3′ — 6 1/4	*Steam :* No information *Electric :* Cast iron
New South Wales (Australia)	*Steam :* 38 Class : Bogie : 3′ 0″ Coupled wheel : 5′ 9″ Trailing truck : 3′ 6″ Special profile near ANZR Std.	*Steam :* 38 Class : Single shoe flanged Cast iron
	Steam : 60 Class : Bogie : 3′ 0″ Coupled wheels : 4′ 7″ Special profile near ANZR Std.	*Steam :* 60 Class : Single shoe flanged Cast iron
	Electric : 4 motors — 37 diameter Wheels ANZR Std. Tyre profile — 5″ wide	*Electric :* 4 motors : Clasp flanged Cast iron flangeless non-metallic
	Electric : 2 motors 42″ diameter wheel ANZR Std. Tyre profile 5″ wide	*Electric :* 2 motors : Clasp flanged Cast iron flangeless Non-metallic

erning the type of rolling stock and its construction *(continued)*.

(g) Type of shock absorbers and vibration dampers	*(h)* Arrangement and spacing of the driving and carrying wheels
team : No shock absorbers or vibration ampers fitted.	*Steam :* Class 15 AR : Arrangement 2.D.1. spacing front to back : 1880- - 1 295 - 1 270 - 1 270 - 1 270 - 2 514 mm Class GMAM : Arrangement 2.D.1. plus 1.D.2 Spacing front to back : 2 083 - 1 295 - 1 473 - 1 448 - 1 473 - 1 473 - 7 823 - 1 473 - 1 473 - 1 448 - 1 473 - 1 295 - 2 083 mm
lectric : 1 E — No shock absorbers 4 E — Have rubber springs 5 E — As vibrator dampers	*Electric :* Classe 1 E : Arrangement Bo plus Bo Spacing : 2 819 - 3 785 - 2 819 mm Class 5 E : Arrangement Bo plus Bo Spacing : 3 429 - 4 420 - 3 429 mm Class 4 E : Arrangement 1 Co plus Co 1 Spacing : 2 205 - 2 337 - 2 286 - 4 724 - 2 286 - 2 237 - 2 205 mm Distance between pivot centres : 10 795 mm
ube stock : Rubber suspension on xle and bolster. Transverse and ertical shock absorber used for olster. urface stock : None.	Nil
team : No information *lectric :* None	*Steam :* No information *Electric :* Axle spacing each bogie : 8′ 6″
Steam : 38 Class : Laminated spring compensated with helical spring anchorage.	*Steam :* 38 Class : Pacific 4 - 6 - 2 
Steam : 60 Class : None fitted	*Steam :* 60 Class : 4 - 8 - 4 plus 4 - 8 - 4 
Electric : 4 motors Hydraulic telescopic	*Electric :* 4 motors - B - B 
Electric : 2 motors None fitted	*Electric :* 2 motors - 2 - B 

Influence of factors extraneous to the track. Fa

Railway	*(i)* Weight and distribution of the loads on the axles
South Africa	*Steam :* Class 15 AR : Total weight : 36 399 kg Axle loads from leading axle : 8 283 - 8 283 - 16 922 - 16 566 - 16 973 - 16 820 - 12 552 Class GMAM (Garratts) : Total : 194 526 kg Axle load from leading axle : 11 078 - 11 078 - 15 143 - 15 656 - 15 550 - 15 093 - 13 060 - 13 365 - 15 448 - 15 855 - 15 956 - 15 448 - 10 900 - 10 900 kg *Electric :* Class 1 E : Total weight : 67 960 kg — Axle loads : 4 × 16 990 kg Class 5 E : Total weight : 84 864 kg — Axle loads : 4 × 21 216 kg Class 4 E : Total weight : 157 530 kg — Axle loads from leading axle : 13 212 + 3 × 21 851 — 3 × 21 851 + 13 212 kg
London Transport	Tube stock : 8.3 — 5.3 — 10.9 — 7.75 tons Surface stock : 10.5 — 6.75 — 14.15 — 9.65 tons
Victoria (Australia)	*Steam :* No information *Electric :* Tare axle loads — 12-ton 11-cwt.
New South Wales (Australia)	*Steam :* 38 Class  *Steam :* 60 Class  *Electric :* 4 motors  *Electric :* 2 motors 

rning the type of rolling stock and its construction *(continued)*.

(j) Effect of loaded and empty vehicles	*(k)* Ratio of the non-suspended weight to the total weight of the vehicle
ot investigated. It would appear that the use of large number of similar heavily loaded vehicles ntributes to the development of corrugations, aded bogie truck, 18-ton per axle, are generally in e Down hill direction, in the Up hill direction the ads are about 28 per cent lighter. Tread diameter truck wheels is 864 mm.	*Steam :* Class 15 AR : 18.9 per cent Class GMAM : 19.4 per cent *Electric :* Class 1 E : 24.9 per cent Class 5 E : 23.4 per cent Class 4 E : 24.6 per cent Trucks unknown
—	Tube stock : 0.22 Surface stock : 0.20
eam : No conclusion *lectric :* No conclusion	*Steam :* No conclusion *Electric :* No conclusion
—	*Steam :* 38 Class : 0.216
—	*Steam :* 60 Class : 0.18
—	*Electric :* 4 motors Suburban : 0.193 Interurban : 0.21
—	*Electric :* 2 motors Motor bogie end : 0.23

BRITISH RAILWAYS.

No comments.

EAST AFRICAN RAILWAYS.

(*a*) Steam.

(*b*) Rods.

(*c*) to (*h*) Various types of locomotives, but mainly « Garrets ».

(*i*) Up to 18 ton on locomotives. Up to 13 ton on rolling stock.

(*j*) and (*k*) No information.

SWEDEN.

Content that corrugation is not influenced by factors extraneous to the track.

NEW ZEALAND.

(*a*) Steam traction, short lengths of electrification — now dieselisation on a wide scale — suburban electric multiple units on short sections.

(*b*) Gears.

(*c*) English electric 660 HP to 1 500 HP and General Motors G, 12 Diesels used on main lines. Duration of the Diesel Electrics is too short to compare with effects of the steam traction.

(*d*) to (*k*) No comments.

SOUTH AFRICAN RAILWAYS.

See Tabulation 1.

ASSOCIATED AMERICAN RAILROADS.

No information relative to effect of these factors on undulatory wear.

EIRE.

(*a*) to (*k*) No data available.

NEW SOUTH WALES.

See Tabulation 1.

LONDON TRANSPORT.

See Tabulation 1.

QUESTION B.

Effect on the growth of undulatory wear of;

(a). — *Frequency of the services.*

General opinion is that undulatory growth depends on frequency of service. This applies to both types of undulatory wear.

(b). — *Speed of the trains.*

The opinions are very divided on this question. India, Japan and New South Wales state that speed does contribute, whilst Victoria, East Africa and Eire are of the opinion that speeds over 30 miles per hour are of no consequence.

INDIA.

(*a*) Exact data not available — rate of progression of corrugation appears to depend on frequency of traffic, but initiation of corrugation apparently independent of it.

(*b*) Speed appears to accelerate the progress of wear.

VICTORIA.

« Roaring » Rail Type.

(*a*) Depth more apparent on frequent service than on light traffic lines.

(*b*) No relation to train speed.

Electric Traction Type. — No comment.

JAPAN.

(*a*) Depends on frequency of service.

(*b*) Speed effects growth of undulatory wear.

BRITISH RAILWAYS.

No comment.

EAST AFRICAN RAILWAYS.

(*a*) Up to twenty (20) trains a day.

(*b*) Maximum 40 miles per hour — average 15 miles per hour.

No other comments.

SWEDEN.

No comments.

NEW ZEALAND.

(*a*) Frequent multiple-unit electric service discloses no appreciable tendency to undulatory wear, as compared to general steam service.

(*b*) No comment.

SOUTH AFRICAN RAILWAYS.

(*a*) Growth of corrugation is relative to volume of traffic.

(*b*) Not investigated.

ASSOCIATED AMERICAN RAILROADS.

No information.

EIRE.

(*a*) Occurs principally where traffic is light — to say twenty-four (24) trains per day.

(*b*) No factor of consequence over, say, 30 miles per hour.

NEW SOUTH WALES.

(*a*) Undulatory growth is proportional to the frequency of service.

(*b*) Higher speed contributes to a more rapid growth of undulation.

LONDON TRANSPORT.

(*a*) No observations.

(*b*) The higher the speed the longer the pitch of corrugations, but braking and acceleration appear to be more important than speed in producing corrugations.

* * *

QUESTION C. — *The Surroundings.*

(a). — *Humidity (neighbourhood of watering places, industrial plants, proximity of the sea, tunnels, etc.).*

Owing to the diversity of opinions expressed on this question, no reasonable conclusions can be reached.

(b). — *Level of the water table.*

Replies so variable that no conclusive finding can be reached.

INDIA.

(*a*) No record of corrugation existing in desert areas, therefore, it appears that humidity is a factor in promoting undulatory wear.

(*b*) No effect.

VICTORIA.

(*a*) Bears no relationship.

(*b*) Due to greater corrosion the Type « A » corrugation is most severe on banks over swampy grounds.

JAPAN.

(*a*) Frequency much greater in tunnels.

(*b*) No comment.

BRITISH RAILWAYS.

(*a*) Particularly liable to occur in or close to mouth of tunnels, traversed by steam trains and at watering troughs. No unusual liability to corrugation has been observed on rails in proximity to sea or in industriel areas.

EAST AFRICAN RAILWAYS.

(*a*) Humid over sea, but mainly dry country.

(*b*) Varies very considerably.

SWEDEN.

No comment.

NEW ZEALAND.

(*a*) Undulatory wear more frequent where damp atmosphere conditions exist.

SOUTH AFRICAN RAILWAYS.

(*a*) Not investigated — corrugation reported to be a little worse in cuttings.

(*b*) Not investigated — water table low on these lines.

ASSOCIATED AMERICAN RAILROADS.

No information.

EIRE.

(*a*) Mainly rural. — Sea air does not appear to effect incidence.

(*b*) Normally 18-feet below rail level is a minimum.

NEW SOUTH WALES.

(*a*) Humidity, etc., is not considered to contribute to undulatory wear to any extent, as undulations also occur on far west areas.

(*b*) No comment.

LONDON TRANSPORT.

(*a*) Corrugations and battering occur more frequently in tunnels than in the open.

(*b*) No observations.

* * *

QUESTION D. — *Homogeneous or diverse traffic.*

(a). — *Combinations due to the factors collected under* A. a), b), i) *and* B. a) *and* b).

No information available from any of the Systems except New South Wales, who reports as follows :

« *Roaring Type* » of undulations, occur under steam traction — rod drive. Corrugation of this type develops very rapidly on high speed tracks where lightly loaded vehicles predominate. Frequency of service and speed of train influences rate of growth.

« Saddle » type occurs under electric multiple-unit traction — with intermediate gearing between motor and axle — nose suspended motors — axle load 14-ton. Frequency of service at comparatively low speeds appear to be one of the main factors in this type of wear. Varying degrees of « saddling » are evident on Sections where concrete road bed exists.

(b). — *Observations made on adjoining tracks and in the stations.*

« Roaring » type generally observed to vary on adjoining tracks. This could possibly be attributed to proportion of light and heavily loaded vehicles on each track. Corrugation not apparent through station platform except « through » running tracks.

« Saddle » type — no appreciable variation apparent except where rising or falling grade. Undulations die out through Stations where on a straight, although they appear on a curved approach (braking) and leaving (acceleration) Station platform.

(c). — *Has wear been found to differ when there is certain particular types of traffic, for example; express passenger trains, freight traffic, passenger traffic, local traffic with frequent accelerations and braking?*

Undulatory wear has been found to differ under various types of traffic. Type « A » mainly associated with steam traction, the corrugations develop more rapidly on tracks where the proportion of lightly loaded goods vehicles is high compared with those with full tonnage loads. With type « B » undulatory wear, no difference is found as this type is mainly associated with multiple-unit electric traction.

Undulatory wear is affected where frequent braking is applied. On steam roads, braking minimises growth whilst under electric traction the tendency is to promote growth.

(d). — *Does the frequence and development of undulatory wear differ according to whether it is a case of single track sections with trains running in both directions, or double track sections carrying similar traffic where the trains run in one direction only?*

Corrugation appears on both lines of double track in varying degrees, on Up lines and Down lines. No factor to incline rail to undulatory wear, which can be connected with the direction of movement can be traced. On single lines where « roarer » type of corrugation occur the pattern is not so clearly defined as in the case of a one direction track.

(e). — *On double track sections on gradients, is the undulatory wear affected by the gradient?*

If so, is the wear more pronounced uphill or downhill according to the direction of the traffic?

Various authorities to this question are not very informative. The diversity of opinion expressed leaves doubts as to whether gradient either up or down grades have any effect on undulatory wear, particularly in regard to the « roaring » type of corrugations. On the New South Wales System corrugations of this type are very similar on both flat gradient and level tracks, but vary on double track according to the frequency of light or heavily loaded vehicles.

Where the gradients are reasonably steep and long the corrugations do not occur to the same extent. This is probably due to braking and slipping, a condition similar to that through stations.

With the Type « B » (« Saddles ») undulatory wear, gradient on curves is largely responsible towards its growth. This type of wear occurs on both Up and Down tracks on sharp curves and is very pronounced on the low rail of a curve on a rising grade.

INDIA.

(*a*) No observations.

(*b*) Corrugations occur only on through running lines. Wear persists even at stations where trains stop, but no cases of corrugations in track adjoining the through running lines at stations have come under notice.

(*c*) All mixed traffic. No other comment.

(*d*) Instances are known when corrugations appear on both lines of a double track, but no factor to undulatory wear can be indicated when the direction of movement has been traced.

(*e*) No information.

VICTORIA.

(*a*) No comments.

(*b*) *Type A.* — « Roaring » rails — severe 2″ pitch in steam and Diesel 70 miles per hour track.

Type B. — « Electric traction » — 30 miles per hour track. — There are no corrugations.

Through stations, undulatory wear dies out, possibly due to braking.

(*c*) Type A. — (Corrugations.) Does not occur with local electric traffic.

Type B. — (Corrugations.) Occur only on electric traction tracks.

(*d*) Observed that with type « A » corrugations, the division between the hard Martensite banks and the softer steel is not clearly defined on single track.

(*e*) Yes. — Wear is more pronounced downhill.

JAPAN.

(*a*) No comment.

(*b*) More frequent in running track — approach to station.

(*c*) Occur most on braking section.

(*d*) More on double than single tracks.

(*e*) More on uphill than downhill.

BRITISH RAILWAYS.

No comment.

EAST AFRICAN RAILWAYS.

(*a*), (*b*), (*c*) No data.

(*d*) Single line only on this system.

(*e*) Gradient appears to have little effect.

SWEDEN.

No comment.

NEW ZEALAND.

(*a*), (*b*), (*c*), (*d*) No comments.

(*e*) Severe traction or braking increases tendency to undulatory wear.

SOUTH AFRICAN RAILWAYS.

(*a*) Not investigated. Traffic mixture of fast goods and passenger service with similar speeds — generally bogie rolling stock.

(*b*) No sharp curves in stations.

(*c*) Not investigated.

(*d*) Not possible to state.

(*e*) All corrugated lines are on steep gradients — 1 — 50 — on electric track develop much faster on down grades — continuous regeneration.

ASSOCIATED AMERICAN RAILROADS.

No information relative to effect of these factors on undulatory wear.

EIRE.

(*a*) No information.

(*b*) Almost unknown through stations.

(*c*) Nearly always associated with braking, regardless of the type of traffic.

(*d*) No difference between single and double lines — occur mostly on approaches to stations and ending at station.

(*e*) Downhill — braking affects corrugations.

NEW SOUTH WALES.

(*a*) *Type A.* — Undulations. — « Roarers. » Occurs under steam traction — rod drive. Corrugations of this type develop very rapidly on high speed tracks where lightly loaded vehicles predominate.

Frequency of service and speed of trains influences rate of growth.

Type B. — « Saddles » — occur under electric multiple unit traction — direct gear drive. Approximately 14-ton axle load. Frequency of service at comparatively low speeds appears to be one of the main factors. Varying degrees of « saddling » — occur on sections where concrete road bed exists.

(*b*) *Type A.* — « Roarers. »

Corrugations vary on adjoining tracks according to the proportion of lightly loaded vehicles on each track. Corrugations are not apparent through station platforms.

Type B. — « Saddles. » — Adjoining tracks up and down directions disclosed no definite variations. Through stations « saddles » are not apparent, although they appear at approach (braking) and leaving (acceleration) stations.

(*c*) Wear classified into two groups, that under Steam « Type « A » and that under multiple-unit electric Type B. On track used by Steam traction the corrugations develop more rapidly on tracks where the proportion of lightly loaded goods vehicles is high compared to those with full tonnage loads. Braking minimises growth of corrugation very appreciably.

(*d*) No information.

(*e*) *Type « A ».*

Yes. Corrugations occur on falling grades, but much less or none at all on steep rising grades.

Type « B ».

« Saddles » — occurs on Up or Down grades, usually more pronounced on rising grades.

LONDON TRANSPORT. « D. »

(*a*) No observations.

(*b*) In and near stations corrugation is caused by braking and acceleration.

(*c*) Battering and corrugations are increased by a light braking.

(*d*) Very short mileage of the L.T.E. track with two-way traffic is relevantly free from corrugations.

(*e*) Heavy down grades and consequent heavy braking produces battering even on straight tracks.

* * *

Summary of Section IV.

TYRE. — RAIL.

Practically no general theory and very few observed facts have been submitted regarding the effect of the wheel on the rail in the initial stage of undulatory wear. Trials and statistics are also practically nil. Opinion expressed is that a form of plastic flow of the metal in rail surface, due to high concentrated pressures, is a principal factor in rail corrugations. These high pressures may develop at low speeds on low side of heavily elevated curves under heavy wheel load (« Saddle » type of undulatory wear) or they may develop due to vibratory condition under high speed movement of relatively light loads (« Roaring » type corrugations). The various authorities are not in accord regarding steel composition, hardness, etc., having any definite bearing on undulatory wear. Investigation has shown, however, that generally corrugation of the « roaring » type is associated with harder rails on straights and flat curves and those of the « Saddled » type with softer rails and practically in all cases on sharp curves. The latter type also occurs where oscillating side thrust or slip of wheels is present.

It is more or less generally reported that braking has the effect of lessening corrugation of the « roaring » type, but tends to increase rate of growth of the « saddled » type of undulatory wear. New Zealand and South Africa have reported that severe traction or braking increases the tendency to undulatory wear. This concerns « saddle » type undulations, which appear to be more prevalent in these two countries.

With « roaring » type corrugation the peaks on formation is converted into a thin layer of « Martensite », which enables the peak to resist more than the troughs.

These high peaks become further « work hardened » well below the rail surface to the extent that excessive grinding is necessary to eliminate the effect of same. Hardness readings taken through crests on a heavily corrugated rail, disclose that the affected zone may be persistent up to 1/4 inch below the surface.

There appears no great change in formation of « saddled » type undulatory wear except that it is increased by the increase in volume and weight of traffic. From the replies received however, it is evident that no reporting Administration has made any serious study of the progress of the physico-chemical phenomena concerned with the formation and growth of corrugation.

Corrosion is considered by some authorities to accelerate the formation of corrugations and to cause it to persist, but very little proof has been submitted to support the theory.

No information has been submitted regarding the incidence of the formation and wear of the tyres on undulatory wear, and the beneficial effects derived from grinding the tyres.

* * *

(a) *Theories, practical trials and statistical inquiries, taking into account* on the one hand *the physico-chemical characteristics of the rail (steel composition, hardness, high limit of elasticity, large moment of inertia, wider running surface) and,* on the other hand, *the effects of the thrust, compression, friction and sliding of the tyre on the rail.*

Practically no general theory and very few observed facts have been submitted regarding the effect of the wheel on the rail in the initial stage of undulatory wear. Trials and statistics are also practically nil. Opinion expressed is that a form of plastic flow of the metal in rail surface, due to high concentrated pressures, is a principal factor in rail corrugations. These high pressures may develop at low speeds on low side of heavily elevated curves under heavy wheel load (« Saddle » type of undulatory wear) or they may develop due to vibratory conditon under high speed movement of relatively light loads (« Roaring » type

corrugations). The various authorities are not in accord regarding steel composition, hardness, etc., having definite bearing on undulatory wear. Investigation does show, however, that generally corrugation of the « roaring » type is associated with harder rails on straights and flat curves and those of the « saddled » type with softer rails and practically in all cases on sharp curves. The latter type also occurs where oscillating side thrust or slip of wheels is present.

(b) *Special observations in connection with the lessening or accentuation of undulatory wear by skidding, braking, pivoting.*

It is more or less generally reported that braking has the effect of lessening corrugation of the « roaring » type, but tends to increase rate of growth of the « saddled » type of undulatory wear. New Zealand and South Africa have reported severe traction on braking — increases tendency to undulatory wear. This concerns « saddle » type undulations, which appear to be more prevalent in these two countries.

(c) *Study of the form of the progression of the physico-chemical phenomena since the formation of undulatory wear began.*

With « roaring » type corrugation the peaks on formation is converted into a thin layer of « Martensitic », which enable the peak to resist more than the troughs.

These high peaks become further « work hardened » well below rail surfaces to the extent that excessive grinding is necessary to eliminate the effect of same. Hardness readings taken through crests on a heavily corrugated rail, disclose the affected zone varies in depth up to 1/4 inch.

There appears no great change in formation of « saddled » type undulatory wear except that it is increased by the increase in volume and weight of traffic. Mushrooming of the running surface of low rail is very evident.

(d) *Influence of corrosion on the formation of undulatory wear.*

Corrosion is considered by some authorities to accelerate the formation of corrugations and to cause it to persist, but very little proof has been submitted to support the theory.

(e) *Incidence of the deformation and wear of the tyres on undulatory wear. Beneficial effects of grinding the tyres.*

No information has been submitted regarding this question.

INDIA.

(*a*) No metallurgical tests have been taken.

(*b*) None.

(*c*) No information.

(*d*) No exact statistical studies have been made.

(*e*) No data available.

VICTORIA.

(*a*) No practical trials have been made and no statistical information is available.

The only theory which has been partly investigated is that put forward by Professor Cramer of the University of Illinois (Bulletin 479 of the AREA) namely, « That the cause of some corrugations is wheel slippages which beat a thin surface layer of the rail above the quenching temperature of the steel, which layer is quickly cooled by the metal underneath (body quench) forming martensite. When such hard spots due to the martensite, are intermittent and the softer areas between them are cold worked lower than the hard areas, corrugations are formed. »

(*b*) « A » type corrugations — « Roarers » — disappear in locations where braking action occurs. Also, the incident of sympathetic corrugations on tyres appears to be affected by percentage of braking on the vehicles.

(*c*) Not sufficient data to provide comments.

(*d*) Type « A » corrugation is most severe in banks over swampy ground.

(*e*) Sympathetic corrugations appear on tyres on this System. However, the deformation is not at present of serious proportion to warrant grinding of tyres.

JAPAN.

(*a*) It is concluded that the wheels give a large impact each time, when they ride over the ridge of undulatory wear and that the Up and Down oscillation of the tracks resinates at a certain train speed, making an infinite amplitude, but actually the magnitude of the impact is limited because the wheels jump up before such speed is reached and with the friction resistance between the laminated plates, constituted bearing springs is, however, effective in reducing the amplitude of oscillation.

(*b*), (*c*), (*d*), (*e*) No comments.

BRITISH RAILWAYS.

(*a*) and (*b*) Corrugation is considered to originate from some form of vibration between wheel and rail. They tend to occur more frequently under corrosive conditions, such as in tunnels traversed by steam trains and on water troughs.

(*c*) Peaks of the corrugations have usually been converted into hard metallographic constituents known as Martensite, which is very wear resisting and that enables the peak to resist wear more than the valleys.

(*d*) Corrosion is considered to accellerate the formation of corrugations and to cause it to persist.

(*e*) No information.

EAST AFRICAN RAILWAYS.

(*a*), (*b*), (*c*), (*d*), (*e*) No data.

SWEDEN.

As corrugated rails are so rare in Sweden, we have not made any trials or observations of the combination tyre-rail on corrugated rails.

NEW ZEALAND.

(*a*) No comment.

(*b*) Severe traction or braking increases tendency to undulatory wear. (Refers mainly to « saddle » type undulatory wear.)

(*c*) No comment.

(*d*) Undulatory wear appears to be more frequent on sections in damp atmospheric conditions.

(*e*) No comment.

SOUTH AFRICAN RAILWAYS.

(*a*) Corrugations occur only on sharpest curves. They increase with decreasing radius. They are worse on Down hills than on Up hill lines and develop more on electric than on steam tracks.

The length of the corrugations are practically equal to sleeper spaces (Saddles). There is no regularity of the depths along curves and along each rail. The deepest corrugation usually occurs between sleeper spaces just beyond a rail joint in the direction of traffic. Reduction of sleeper spacing reduces the corrugations.

The provision of lateral buttresses on the outside of check rails increases the corrugation.

Mushrooming of the surface of the top surface of the rails is more noticeable on the inner rail.

(*b*) Regenerative braking on electric down hill lines is a contributing factor.

(*c*) There has been no great change in the forms of corrugations except that it is increased by the increase in volume and weight of the traffic.

(*d*) No investigation.

(*e*) No investigation.

ASSOCIATED AMERICAN RAILROAD.

(*a*) In most cases of undulatory wear, the crests are covered with a very thin layer of « Martensite » and the hollows are normal pearlitic steel composition. Since the « Martensite » is formed by local heat and quenching, it is presumed that the heating only can be caused by sliding of the wheel on the rail surface.

(*b*) There is some question whether undulatory wear develops first and the « Martensite » forms only at the contact areas on the crests, or the « Martensitic » areas form first and their increased resistance to corrugation and wear results in formation of the crest.

There are indications that braking has affected the undulatory wear, also there are a few instances where undulatory wear has occurred and braking is obviously not affected.

(*c*) It is, in our opinion, a form of plastic flow of the metal in the rail surface, due to high concentrated pressure, is a principal factor in rail corrugations. They may develop at low speeds on the low side of heavily loaded curves, under heavy wheel loads or they may develop due to vibratory conditions under high speeds of relatively light loads.

(*d*) and (*e*) No comments.

EIRE.

(*a*) No information.

(*b*) Corrugations are definitely associated with places where trains normally are braking and they are only found where skidding takes place or stopping at stations.

(*c*), (*d*), (*e*) No information.

NEW SOUTH WALES.

(*a*) High carbon rails show greater tendency to corrugate than low carbon rails. Similar rails of approximately the same chemical composition, but with different hardnesses — the hard rail will corrugate quicker than softer rails. Light loaded vehicles at comparitively high speed contribute to corrugations.

« Saddled » type undulations — occur where oscillating side thrust or slip of wheels is present.

(*b*) Braking has effect of lessening corrugations, but increases rate of growth on « saddles ».

(*c*) After the formation of corrugation, rails will work harden to a depth of approximately 1/4 inch below the surface. The metal in the crests is harder than in the troughs.

(*d*) No information.

(*e*) No information.

LONDON TRANSPORT.

(*a*), (*b*), (*c*), (*d*), (*e*) No observations.

* * *

Summary of Section V.

EFFECT OF UNDULATORY WEAR ON THE TRACK, BRIDGES AND VIADUCTS AND THE ROLLING STOCK.

Rail corrugation of both types is reported by most Railway Systems to cause loosening of rail fastenings. Where corrugation is very heavy great difficulty is experienced in holding anchors on the rail and elastic type spikes are known to break off where they enter the sleepers.

Excessive rail cutting of sleepers is definitely caused by undulatory wear. Instances are recorded that up to 17 % more sleepers are rail cut under rails with undulatory wear than in sections without.

Practically no information has been submitted by any of the Systems regarding the effect of undulatory wear on steel bridge

components, transoms, fastenings, bearing plates, fastenings and damage to piers, abutments, etc. Some mention is made that undulatory wear has an adverse effect on supporting structures in varying degrees, but no particulars have been submitted.

Investigations in regard to the effect upon the rolling stock are very meagre and not conclusive. India, Victoria and Japan have reported sympathetic effect on tyres and breakage of unsprung components.

* * *

Question 1. — Has your experience enabled you to state that undulatory wear leads to :

(a) *The loosening and wear of the rail spikes, rail anchors, fishplates and fishplate bolts and base plates :*

Corrugated rails, both types, are reported by most Railway Systems to cause wear and loosening of rail fastenings. South Africa and India report no loosening of rail anchors due to corrugations. South Africa is only concerned with « saddled » rails. New South Wales has reported that where elastic spikes are used under heavily corrugated rails many have broken where they enter the sleepers and extreme difficulty is experienced in keeping rail anchors tight on the rail.

(b) *The wear of the sleepers :*

Yes, practically all the Systems report this trouble under corrugated rails. Instances are recorded that up to 17 % more sleepers are rail cut under rails with undulatory wear than in sections without.

(c) *The loosening of the nuts, the bolts fastening the transoms to the stringers of bridges and/or the breaking of these bolts.*

(d) *The failure of rivets and bolts in the connections between stringers and cross girders and between cross girders and main girders of bridge.*

(e) *Wear of the pins and plates of the bridge bearings.*

(f) *The loosening of the holding down bolts and the destruction of the mortar between the base of the bearings and the piers.*

(g) *Damage to the piers and abutments.*

(h) *Fatigue failures of the stringers, cross girders, main structure and bracing of bridges.*

(i) *Damage of the invert of tunnels or to the drains.*

For sub-questions (*c*) to (*i*).

No apparent damage reported. Japanese and the American Railways suggest that undulatory wear does affect the locations mentioned in varying degrees, but have no records on hand.

New South Wales reports loosening and wear of transom bolts on bridges and damage to bedplates and bridge abutments.

INDIA.

(*a*) There are complaints of loosening of rail spikes, fishplates and fish bolts, but none about rail anchors.

(*b*) No data available, but reports to the effect that there is accelerating destruction of sleepers at the foot of the rail.

(*c*) No definite observation yet available.

(*d*), (*e*), (*f*), (*g*), (*h*) No effects on bridges or bridge structures has been reported.

(*i*) No damage to tunnels or drains.

VICTORIA.

(*a*) to (*i*) No.

JAPAN.

(*a*) Yes. Also, undulatory wear causes the slope of the ballast to collapse, reducing the covering of sleepers.

(*b*) Causes rail to cut more into sleepers. It has been recorded that 17 % more sleepers are cut in under rails with undulatory wear, than in sections without.

(*c*) to (*i*) Rather positive that undulatory wear does affect the locations mentioned, although no record on hand.

BRITISH RAILWAYS.

No comments.

EAST AFRICAN RAILWAYS.

(*a*) Some loosening of steel keys.

(*b*) to (*i*) No data.

SWEDEN.

No records available.

NEW ZEALAND.

(*a*) No comments.

(*b*) Yes. Excessive sleeper wear is due to « roaring » rails.

(*c*) to (*i*) No comments.

SOUTH AFRICAN RAILWAYS.

(*a*) Corrugations cause loosening of keys and chairs and coach screws. Spikes and anchors do not exist.

(*b*) Probably wear out screw threads.

(*c*) (*d*) (*e*) (*f*) (*g*) (*h*) No bridges.

(*i*) No sharp curves in tunnels.

ASSOCIATED AMERICAN RAILROADS.

(*a*) Definitely induces wear of spikes and joint bars.

(*b*) Wear of sleepers apparent.

(*c*) (*d*) (*e*) (*f*) (*g*) (*h*) Undulatory wear has a diverse effect on supporting structures in all these particulars.

(*i*) No effect.

EIRE.

(*a*) and (*b*) Corrugated rails definitely increase the wear under rails and base plates of sleepers and also damage rail fastenings, making it difficult to maintain them properly.

(*c*) to (*i*) No damage to bridges has been noticed.

NEW SOUTH WALES.

(*a*) Yes — all fastenings mentioned. Corrugated sections. Where elastic spikes are used many are broken off where they enter sleepers and extreme difficulty is experienced in keeping rail anchors tight on the rail.

(*b*) Yes.

(*c*) Yes.

(*d*) No definite information.

(*e*) No.

(*f*) Yes.

(*g*) Yes. In a few cases only on high speed tracks, cracking of brick abutments.

(*h*) No.

(*i*) No.

LONDON TRANSPORT.

(*a*) Yes.

(*b*) to (*i*) No — measures have to be taken to avoid any serious vibration from undulatory wear being transmitted to surrounding properties.

* * *

Question 2. — Effects upon the rolling stock.

(a) *Sympathetic corrugations in the tyres of the wheels.*

India and Victoria only Systems reporting a form of sympathetic corrugation on tyres. Pitch is claimed to be similar to those on « roarer » type corrugated rails, but much shallower.

(b) *Increase in the wear of the axle bearings, journals, axle guards, springs, etc.*

(c) *Fatigue and breaking of springs and brake rigging.*

(d) *Loosening of the tyres.*

(e) *Loosening of white metal bearings.*

For sub-questions (*b*) to (*e*).

No information has been reported except American Railways and New South Wales, who state, no data available, but have no doubt that vibrations induced by undulatory wear have an adverse effect on these parts.

* * *

INDIA.

(*a*) Locomotives and rolling stock on sections having corrugated rails have been shown on sympathetic effects in the period between periodical overhaul when the tyres are skinned.

(*b*), (*c*), (*d*), (*e*) No effect of this kind has been reported.

VICTORIA.

(*a*) Type A. — Corrugations — disclose a form of sympathetic corrugations on the tyres. The pitch of these corrugations approximates the pitch of the undulatory wear of the rails, but is much shallower.

(*b*), (*c*), (*d*), (*e*) No.

JAPAN.

(*a*) to (*e*) Undulatory wear is able to accelerate fatigue, breakage of unsprung components and lead to wear, loosening and damage of such parts. No positive data is available.

BRITISH RAILWAYS.

No comments.

EAST AFRICAN RAILWAYS.

(*a*), (*b*), (*c*), (*d*), (*e*) No data.

SWEDEN.

Corrugated rails have no effect on rolling stock.

NEW ZEALAND.

(*a*), (*b*), (*c*), (*d*), (*e*) No.

SOUTH AFRICAN RAILWAYS.

(*a*) Nothing of this nature has been found.

(*b*) Not investigated.

(*c*) Breakages have occurred, but cannot be attributed to corrugated rails.

(*d*) and (*e*) No information available.

ASSOCIATED AMERICAN RAILROADS.

No records available, but have no doubt that vibrations induced by undulatory wear have a diverse effect on rolling stock.

EIRE.

No data available.

NEW SOUTH WALES.

(*a*) No.

(*b*), (*c*), (*d*), (*e*) No data, but have no doubt that vibrations induced by undulatory wear have an adverse effect on most of these component parts.

LONDON TRANSPORT.

(*a*) to (*e*) No — measures have to be taken to avoid any vibration from undulatory wear being transmitted to surrounding properties.

* * *

Question 3. — Have you found it possible to estimate the cost of the damage caused to the rolling stock by undulatory wear of the rails?

If so, does the extent of the damage bear any relation to the degree of undulatory wear? (Such an estimate would be of the greatest importance in decid-

ing the expenditure that would be justified to prevent it or the cost of the measures taken to remedy undulatory wear.)

No information available from any of the Railway Systems.

* * *

INDIA.

Corrugations are still not a serious problem. No definite information available regarding this question.

VICTORIA.

No comments.

JAPAN.

No comments.

BRITISH RAILWAYS.

No comments.

EAST AFRICAN RAILWAYS.

No data.

SWEDEN.

No information.

NEW ZEALAND.

No.

SOUTH AFRICAN RAILWAYS.

No.

ASSOCIATED AMERICAN RAILROADS.

Not possible to estimate.

EIRE.

No data available.

NEW SOUTH WALES.

No.

LONDON TRANSPORT.

No observations.

* * *

Summary of Section VI.

MEASURES TAKEN TO AVOID UNDULATORY WEAR OR TO REMEDY IT.

New South Wales is the only System which has made any investigation into the effect of relaying corrugated rails on sharp curves. Rails with roaring type corrugations 0.015 inches deep were relayed in 16 chains to 20 chains radius reverse curves, on single line in August, 1949, and recent reports disclose that the corrugations have entirely disappeared whilst on the 1 chain length of straight track and portion of the transitions joining the curves, the corrugations still exist with depths of corrugations in the vicinity of 0.010 inches.

The insertion of rubber pads between rails and sleeper plates have been under test in various countries for some time with some success, but results at this stage cannot be considered as conclusive.

The use of elastic spikes does not appear to minimise the growth of corrugation.

British Railways has reported that with partial resleepering with concrete sleepers mixed with timber, corrugations have disappeared. Other Systems have not commented.

Grinding of rails, unless carried out as routine maintenance, i.e. constant grinding in the initial stages of development, has not proved satisfactory. It has been found that corrugations re-appear in very short time after grinding. New South Wales reports that corrugations re-appear in exactly the same positions along the rails. Evidently no grinding of rails with « saddle » type undulations has been carried out.

Various methods of grinding rails in shops and insitu have been adopted by the various authorities. Japan and the American Railroads report using special trains consisting of several cars each having several sets of grinding wheels. Cup type grinding wheels are used rotating in a plane parallel to the track. These wheels are mounted in multiple and inclined at

the various angles so as to cover the entire running surface of the head. Japan has given the extent of grinding as 0.03 to 0.05 mm at speed of about 3 km per hour. East Africa uses four (4) wheel vans converted using carborundum blocks under pressure of approximately 75-lb. per square inch travelling at speeds up to 30 miles per hour, usually 40 to 50 passes required to remove corrugations. New South Wales used this method some years ago, using a bogie type van at speeds up to 6 miles per hour, but discarded it as too slow in operation and because the corrugations grew rapidly again.

Heat treatment of rails, before (« sorbitising ») or after corrugations have formed, does not contribute to elimination or minimising of corrugations. Flame treating after grinding corrugations has not been successful. The use of paints and protection coating against corrosion has not been seriously considered.

Grinding of new rails or periodical rectification of tyres by grinding to avoid or remedy undulatory wear has not been undertaken by any of the reporting authorities.

* * *

Question. — Have any of the following measures been taken and, if so, with what results?

(a) *Taking up rails with serious undulatory wear from straight sections or flat curves and relaying them on sharp curves, where normally undulatory wear does not occur.*

No reports except New South Wales. Recovered corrugated rails « roaring » type to 0.015 inches depth were relayed on a reverse curved track 16 chains to 20 chains radius, single line, in August, 1949. The corrugations have now entirely disappeared, whilst on the 1 chain length of straight track and portion of transition joining the curves, the corrugations still exist with depths of corrugations in the vicinity of 0.010 inches.

(b) *Inserting a rubber pad between the foot of the rail and the sleeper bearing plate or between the bearing plate and the sleeper or transom.*

Some Systems are carrying out tests, but most so far are not yet conclusive. Victoria has had reasonable results with rubber pads on straight tracks over subways, under multiple-unit electric traffic (low speed). After eighteen (18) months no deterioration has occurred. British Railway also reports relaying « Sorbitic » rails « Roaring » corrugated, on concrete sleepers and rubber pads and after two (2) years no change noticed. New South Wales is making tests with rubber pads between rail and bearing plate but no conclusive evidence yet.

(c) *The use of elastic fastenings to attach the rails to the sleepers.*

New South Wales and Japan are using some elastic spikes at a number of locations, but tests are not yet conclusive.

(d) *Reduction or increase of the number of sleepers per rail.*

British Railway has reported partial resleepering with concrete sleepers mixed with timber, corrugations have disappeared. Other Systems no comments.

(e) *Has grinding been used to remove undulatory wear and, if so, with what results?*

Systems, which have carried out grinding have reported that corrugations reappear a very short time after. New South Wales reports corrugations re-appear in exactly same position after three (3) months.

(f) *Have the rails been heat treated, either before or after undulatory wear and, if so, with what results?*

Corrugated rails (« Roaring » type) have been heat treated, but found to corrugate

again in very short time. Japan and Associated American Railroads has reported heat treating new rails, result not yet conclusive.

(g) *Any other measures?*

New South Wales has carried out tests by grinding corrugated rails (« Roaring ») to just below surface in troughs and heat treating. Corrugation re-appeared in same position in three (3) months.

(h) *The use of paints and protective coatings against corrosion.*

No comments.

(i) *Methods of grinding the rails in the shops or on the track by the use of special vehicles.*

Japan resurface corrugated rails by planing in the Workshops, also by grinding in the field using vertical grinder. Extent of grinding 0.03 to 0.05 mm at speed of about 3 km/h.

East Africa uses a 4 wheel van converted using carborundum blocks under pressure of approximately 75-lb. per square inch. Hauled by engine at about 30 miles per hour. Usually 40-50 passes required to remove corrugation.

Associated American Railroads carry out rail grinding using special grinding train consisting of several cars each having several sets of grinding wheels. Cup type grinding wheel rotated in a plane parallel to the surface of the track. These wheels are mounted in multiple and inclined at various angles so as to cover the entire running surface of the rail head.

New South Wales has experimented with specially rigged grinding wheel in a depot.

The carborundum wheel periphery ground to form top running surface. Some years ago rails were ground insitu using carborundum rubbing blocks fitted to bogie type van. This van hauled by an engine at about 6 miles per hour did a good job, but proved too slow in operation and because the corrugations grew rapidly again was discarded.

(j) *Cleaning the running surface of the rails with metal brushes mounted on locomotives.*

No comment.

(k) *Trials of grinding the rails before laying them to eliminate any undulations that may already exist.*

No comment.

(l) *Periodical rectification of the tyres by grinding.*

No comment.

INDIA.

Nothing has been done so far. Undulatory wear is not a serious problem in India.

VICTORIA.

(*a*) No corrugated rails have been relaid in sharp curves.

(*b*) Rubber pads were installed in one location on a straight over subway, under multiple-unit electric traffic. (Low speed.) After eighteen (18) months no deterioration has occurred.

(*a*) and (*d*) No.

(*e*) Corrugations re-appear soon after grinding.

(*f*) Flame treatment was carried out as a test, but was not concluded.

(*g*) (*l*) No.

JAPAN.

(*a*) No comments.

(*b*) Tests not yet conclusive.

(*c*) Used in System — time is too short to furnish convincing facts.

(*d*) No — not attempted.

(*e*) Found to occur again after grinding.

(*f*) No experience of heat treatment after start of undulatory wear. These heat treated rails were laid in late 1952 (about 45 718 km of running track to date).

No data available.

(*g*)

(*h*) No comments.

(*i*) Corrugated rails are planed in the Workshop and ground in the field, using vertical spindle type grinder — speed of train about 3 km per hour. depths of corrugations 0.03 to 0.05 mm.

(*j*) No comments.

(*k*) Rails for re-use sometimes ground in Workshop.

(*l*) The grinding of tyres is a routine practise, though not for the purpose of preventing undulations.

BRITISH RAILWAYS.

(*a*) No comments.

(*b*) « Sorbitic » rails (corrugated) relaid on concrete sleepers and rubber pads — after two (2) years no change noticed. Also, corrugations disappear in partial resleepering with concrete sleepers.

(*c*) No data.

(*d*) Partial resleepering with concrete sleepers mixed with timber. The corrugations have disappeared.

(*e*) No comment.

(*f*) Heat treated to produce « Sorbitic » structure on the running surface have been found to be very liable to corrugations.

(*g*) (*h*) (*i*) (*j*) (*k*) (*l*) No.

EAST AFRICAN RAILWAYS.

(*a*) (*b*) (*c*) (*d*) No.

(*e*) Corrugations removed by grinding. No comments as to the results.

(*f*) (*g*) (*h*) No.

(*i*) Method of grinding four wheel van conveyed into rail grinding vehicle using carbon locks under a pressure of approximately 75-lbs. per square inch. Speed of train — 30 miles per hour requires about 40 to 50 passes to remove corrugation.

(*j*) (*k*) (*l*) No.

SWEDEN.

No special measures taken to remove corrugations.

NEW ZEALAND.

(*a*) No.

(*b*) (*c*) Yes, but not primarily to reduce undulatory wear.

(*d*) (*e*) No.

(*f*) Early experience with the « Sandberg Sorbitic » process was very unsatisfactory as regard the undulatory wear.

(*g*) (*h*) (*i*) (*j*) (*k*) (*l*) No.

SOUTH AFRICAN RAILWAYS.

(*a*) No.

(*b*) (*c*) Tests are planned.

(*d*) No.

(*e*) Corrugations too long and deep for grinding.

(*f*) No.

(*g*) See Section 4. — Type Rail.

(*h*) (*i*) (*j*) (*k*) (*l*) No.

ASSOCIATED AMERICAN RAILROADS.

(*a*) Rails with undulatory wear relaid in other locations on tangent or curved tracks has resulted in undulatory wear completely disappearing in a few months of service.

(*b*) No information.

(*c*) No information.

(*d*) Not tried.

(*e*) Grinding of rails has been carried out at speeds of about 20 miles per hour. No comments concerning result of such grind.

(*f*) Some tests have been carried out with heat treated rails in track, but so far no undulatory wear has developed in them.

(*g*) (*h*) Nothing to report.

(*i*) Rail grinding carried out with a grinding train consisting of several cars, each having several sets of grinding wheels utilising the flat surface of a cup type grinding wheel, rotating in a plane parallel to the surface of the track, the wheels inclined at various angles to uncover the entire running surface of the rail head.

(*j*) (*k*) (*l*) Nothing to report.

EIRE.

(*a*) (*b*) (*c*) (*d*) No.

(*e*) Grinding carried out within the period of two (2) years — results, so far, have been satisfactory.

(*f*) No.

(*g*) None.

(*h*) (*i*) (*j*) (*k*) No.

(*l*) No comments.

NEW SOUTH WALES.

(*a*) Test rails corrugated to depth up to 0.015 and relayed on a reverse curve track of 16 to 20 chains radius during August, 1949. The corrugations have now entirely disappeared. Whilst the 1 chain length of straight track joining the curves, the corrugations still exist with depths in the vicinity of .010 inches.

(*b*) Although extensive tests have been carried out the results have not been conclusive.

(*c*) Have used elastic spikes, but no information available.

(*d*) Not tried.

(*e*) Yes — but corrugations re-appear in exactly the same position in about three (3) months.

(*f*) Yes — after undulatory wear, but corrugations re-appear in exactly the same position in about three (3) months.

(*g*) The combination of grinding, followed by treatment, corrugations re-appear in the same position in three (3) months.

(*h*) No. Not on the top running face. Tests have been carried out using paints, etc., for protection against corrosion of rails in tunnels but results are not satisfactory.

(*i*) Both methods tried, with above results.

(*j*) (*k*) (*l*) No.

LONDON TRANSPORT.

(*a*) No.

(*b*) Many experiments — have shown no benefits.

(*c*) Experiments in hand — shown no benefits.

(*d*) No.

(*e*) Grinding is a normal maintenance process to remove corrugations and battering.

(*f*) No.

(*g*) None.

(*h*) No.

(*i*) Rails removed from the track are planed or milled before replacing, with very satisfactory results. Grinding on the track is by fixed shoes on motor vehicle.

(*j*) (*k*) (*l*) No.

* * *

Summary of Section VII.

RESULTS OF SYSTEMATIC RESEARCH WORK.

No systematic research has been reported. Some Authorities have undertaken various tests, but with the exception of New South Wales have not reported any progress. The Associated American Railroads has not carried out any individual research, but reference is made to investigations made by Professor R. E. Cramer at the University of Illinois for the AREA Rail Committee. He conducted experiments using an acetylene torch to tamper the Martensitic area and found that following this the crests disappeared in track. No satisfactory explanation is found regarding formation of Martensitic area.

Investigations carried out by New South Wales to date is not conclusive, this work is still in hand.

Aims of Test.

(1) Use of rubber pads between rail sleeper plate to inhibit rate of growth of corrugation.

(2) To test effect of grinding off corrugation and heat treating of rail surfaces.

(3) To watch the growth in the light of various theories. Vibration test of vehicles to ascertain if they synchonize with the frequency of corrugation in the locality.

Whilst the tests are still proceeding the results to date lead to the following conclusions :

(1) The rubber pads have had little effect on the growth of corrugation.

(2) Neither grinding nor normalising the rail surface can remove all traces of the former corrugations.

(3) There are no vehicles vibrating and hammering the track at the frequency of the corrugations in the test locality.

No laboratory investigations have been done by any of the Railway Systems.

* * *

Section VII.

RESULTS OF SYSTEMATIC RESEARCH WORK.

(a) *On trial sections, giving the various arrangements made and the material and rolling stock used :*

(b) *In the laboratory by causing undulatory wear on test rails.*

INDIA.

(*a*) and (*b*) No research work has been done so far.

VICTORIA.

(*a*) and (*b*) No tests made.

JAPAN.

(*a*) No systematic research has been done in providing a trial section. Observation disclosed that undulatory wear occurs more on sections where electric cars are operated.

(*b*) No comments.

BRITISH RAILWAYS.

No comments. — Reference is made to Mr. T. Turner's paper « Roaring Rails ».

EAST AFRICAN RAILWAYS.

(*a*) and (*b*) No systematic research work undertaken.

SWEDEN.

Have nothing to say to this question.

NEW ZEALAND.

(*a*) and (*b*) No.

SOUTH AFRICAN RAILWAYS.

(*a*) No special rolling stock used. Depths and lengths of corrugations measured periodically. (Further reference, see Section IV.)

(*b*) Not tried.

ASSOCIATED AMERICAN RAILROADS.

Investigation by Professor R. E. Cramer of Illinois University. Observations and measurements on rails with undulatory wear show that the spotty « martensitic » areas developed on rail running surface due to intermittent slipping of the driving wheels and that these « martensitic » area wore at a slower rate than the remainder of the rail causing crests to develop. On heating the « martensitic » areas with oxy-acetylene torch to tempering heat, it was found that following this the crests disappeared in the track. No satisfactory explanation is found regarding formation of the « martensitic » areas.

EIRE.

No research work has been carried out.

NEW SOUTH WALES.

(*a*) On steam traction track where corrugations were previously prevalent.
Aim of Test :

(1) Use of rubber pads between rail and sleeper plates to inhibit rate of growth of corrugation.

(2) To test effect of grinding off corrugation and heat treating of rail surface.

(3) To watch the growth in the light of various theories. Vibrations test of vehicles to ascertain if synchonize with frequency of corrugation in the locality.

Test still in progress, results to date :

(1) Rubber pads have had little effect on the growth of corrugation.

(2) Neither grinding nor normalising the rail surface can remove all traces of the former corrugations.

(3) There are no vehicles vibrating and hammering the track at the frequency of the corrugations in the test locality.

LONDON TRANSPORT.

(*a*) and (*b*) No observation.

* * *

Section VIII.

MEASURING AND RECORDING EQUIPMENT.

(a) *Of undulatory wear;*

(b) *To determine the elastic stresses in the rails;*

(c) *Description of the equipment and methods used.*

(*a*) Equipment used for measuring undulatory wear generally reported to consist of straight edges 2 to 4 feet long, in conjunction with various types of dial indication measuring to 0.0001 of an inch, or feeler gauges. Where depressions are deep such as occur in « Saddles », straight edge and wedge gauge.

(*b*) The types of equipment to determine the elastic stresses in the rails, have been submitted by the different authorities. They consist mainly of electric resistance type strain gauge recorders.

(*c*) Description of the equipment and methods used.

INDIA.

Variation in undulatory wear is measured with a 3-feet long straight edge steel square and feeler gauges.

Electrical wire resistance strain gauges — oscillograph equipment have been used. No separate studies have been conducted to find the stresses in corrugated rails as distinguished from rails not corrugated.

VICTORIA.

Type « A ». — Straight edge with dial indicator for measuring pitch and depths.
Hardness measure with « Brinell » portable hardness tester.

Type « B ». — Straight edge and taper gauge.
Dynamic wire resistance strain measuring equipment by Hathaway Instrument Company, consisting of the following units :

1. Power supply unit (Type PSA-17) consisting of rectifier, regulator and oscillator

sections supplying power for operation of the strain gauge control unit.

2. Strain gauge control unit (Type MRC-17) consisting of amplifier and demodulator units.

3. Photographic recording oscillograph (Type S8-B) containing galvanometers of the bifilar type.

The strain gauges used with this equipment are of the Baldwin SR-4, Phillips or Tinsley type.

Due to the shortage of technical staff and more urgent work, stress measurements on rails, which have been commenced, have had to be terminated.

JAPAN.

Wire resistance strain gauge in measuring stresses in rails.

Wire strain gauge is stuck to the upper part (gauge side) of rail base at respective positions of ridge, groove and mid-slope of undulatory wear, in order to measure stresses in rails caused by trains running on the track. Also, deflection gauges are attached to the lower side of the bottom of rail in order to measure deflection in the middle part of rail base when trains run on the track.

BRITISH RAILWAYS.

Refers to the British Railways Research Department report Nos. E145 and E69 which deals with « Measurement of rail corrugation on concrete sleepered track with resilient pads » and « A preliminary investigation into the magnitude and frequency of dynamic stresses in elastic rail spikes ».

EAST AFRICA.

No information.

SWEDEN.

Do not use any special measuring and recording equipment for studying corrugating of rails.

NEW ZEALAND.

Tests have been carried out, but not primarily for undulatory wear.

Extensive wire resistance strain gauge, stress and load measurements have been made under steam, diesel and electric locomotives on straight and curved track to determine the main stress on base of rail and vertical and lateral loads between rail and sleepers. Head contact stresses have not been regarded as critical on the New Zealand System, so that stresses of this nature were not specially measured.

Record of sonic frequencies were made using the 2 000 cycle response equipment and the results appeared to be in line with French experiments.

Equipment designed and built by the New Zealand Department of Scientific and Industrial Research and included :

1. A 1 000 cycle per second response six channel simultaneous Cathode Ray Tube recorder, complete with camera.

2. A 2 000 cycle per second response six channel Cathode Ray Tube recorder, complete with photographic attachments.

SOUTH AFRICAN RAILWAYS.

Straight edge and wedge gauge for measuring depth of corrugations.

Measuring lengths and depths of corrugations over 3 rail-lengths, beginnings, middles and ends of curves. Analysis not fully undertaken, mostly based on life of rails.

ASSOCIATED AMERICAN RAILROADS.

A 48-inch straight edge supported at each end on the running surface with sliding « Ames » dial to determine the profile of the top surface of the rail through the area containing the undulatory wear.

For determining the bending or flexural stresses in the rail base, we use « Baldwin-Southwork SR4 » type gauge with electronic amplifiers and magnetic galvanometers designed to accurately record a frequency of 1 500 cps, which have been found fast enough to accurately measure impact effects of this nature in the rail.

By placing Statham accelerometers having a natural frequency of 1 500 cps, on some of the sleepers in the area containing undulatory wear and make records with the same amplifying and oscillographic recording equipment to show the dynamic effects upon the tie accelerations.

All the measurements described above we would make on rails containing undulatory wear, obtaining these records under a sufficient number of trains, then we would have the rail ground to remove all undulatory wear and the measurements repeated to determine the effect of undulatory wear on the rail profiles, flexural stresses and tie accelerations.

EIRE.

No research work has been carried out.

NEW SOUTH WALES.

The equipment utilised on the various phases of tests carried out on undulatory wear consists as follows :

Accelerometer, tape recorder and a frequency analyser. These instruments were used to obtain a measurement of the resonant frequency of incipient corrugation in the vicinity of 2 — inch pitch at a speed of 30 m per hour. This was found to be 340 cycles per second. The pick-up unit was an accelerometer attached to the foot of the rail.

(2) « Vibrograph » instrument to record extent of vibration transferred from rail to road bed at various speeds.

(3) Straight edge supported by bracket on top of rail flange with dial gauge, for measuring extent of corrugation. Dial gauge accuracy to 0.0001 of an inch — pitch measured to 1/16 of an inch accuracy.

(4) A four (4) channel strain measuring bridge manufactured by New South Wales Railways with a carrier frequency of 2 000 cycles per second, attached to a « Kelvin and Hughes » four (4) channel pen recorder. This equipment was used to measure vertical and lateral loads on corrugated track in comparison to non-corrugated track. No conclusive results were obtained by use of above instrument.

LONDON TRANSPORT.

Straight edge and feeler gauge.

[625 .123 (71)]

" Inoculated " roadbed heaves no more.

(*Railway Track and Structures*, September, 1957.)

A chemical derived from the sulphite liquor waste obtained from pulp manufacture is successfully eliminating, on the Canadian National, the need for shimming track as shown in the photograph. Costing an average of about $ 1.00 per track-foot, the chemical treatment promises, it is said, a 100 % return on the investment.

As the winter of 1951 closed in on that stretch of Canadian National track which lies between Mileposts 104 and 105 on the Jonquiere subdivision an all-too-familiar story began to unfold.

Capillary moisture, creeping upward through the subsoil, had formed layers of water at and above the frost line beneath the roadbed. With the first « hard » freeze, this water solidified and, as it was transformed into ice, expanded as only water will do. The pressure created by this expansion thrust the now hardened roadbed upward. The more water that collected, the greater the expansion, and the farther the track was heaved up. Slow orders were issued and maintenance crews installed wooden shims between the tie plates and the ties to provide run-offs from the heaved spots. Nature had again performed her annual track « raise » at this and uncounted other locations on the railroad.

Scenes like this are disappearing on the Canadian National.

Between MP's 104 and 105, some $ 108 were spent in the winter of 1951-52 for shim materials, while some $ 96 were expended in labor to install the shims and then, as spring came, to remove them as the track settled to its former level.

During the following four winters, on the other hand, a grand total of only $ 14.68 was spent for shim materials and a mere $ 59.88 expended for the necessary labor which, in the interim, had become a progressively higher-priced commodity. What had happened to bring about this considerable reduction in costs — and average annual savings of over

$ 175? Just this: Frost heaving had been cut drastically through injections into the roadbed of a chemical derived from a by-product of sulphite pulp manufacture — called Lignosol.

It was almost six years ago now that Lignosol Chemicals, Ltd., Quebec City, Que., first attempted chemical control of frost heaving in co-operation with the CNR at the location referred to. A 100-ft long section of track where annual heaving had been particulary severe was treated. The heaves promptly disappeared. They have not recurred since, nor has the treatment been repeated. Heartened by this early success, which came upon the heels of years of extensive research and laboratory testing, additional sections of track were treated.

Through 1956, the CNR had applied Lignosol at 34 separate locations, according to the manufacturer. This company estimates that the average annual savings incurred by eliminating the need for shimming is about $ 740 in materials and $ 2 400 in labor. The cost of the Lignosol applied through the winter of 1955-56 was some $ 3 100 to which is added a labor cost of $ 2 650. The total cost of applying Lignosol — $ 5 750 — is considered an investment inasmuch as the average savings per year in shimming materials and labor run well over $ 3 000 for the 34 locations so treated.

All in all, for the 34 locations where Lignosol was applied, an annual return of about 56 per cent on the original investment is being realized. Reports are that no location which has been so treated has required a second application.

Injection pipe for applying Lignosol to the roadbed is driven to a predetermined depth with a jackhammer.

What is Lignosol?

Lignosol is a chemical derived from the sulphite liquor waste obtained in the production of pulp for paper manufacture. According to the manufacturer, the product is a dispersant which, combined with subsoil compaction under traffic, effectively reduces the permeability of the subsoil to the extent that frost heaving

is virtually eliminated. After innumerable tests in the laboratory and in the field, the manufacturer points out: « It remains to be established conclusively that reduction in permeability is the reason for elimination of frost heaving; for the present, it is the best explanation we have ».

Frost heaves, according to Lignosol spokesmen, are not due to the freezing of moisture initially present in the soil, but rather to the freezing of water brought up to the frost line by capillary action. This movement they explain, results in the formation of layers of ice in the soil at the frost line that may attain considerable thickness. The important factors of this process, which are extremely variable, are the distance from the frost line to the groundwater level, the grain size distribution of the soil, and permeability.

In clean gravel or sand, in which there is practically no capillary movement of moisture, the growth of ice layers at the frost line does not occur, say Lignosol technicians. In a clay soil, they add, the capillary movement of moisture is so slow that large ice layers do not form. However, in soils whose grain size is intermediate between that of clean sands and clays, that is, silty sands, and silt soils, maximum growth of ice layers occurs because of the comparatively rapid rate at which capillary moisture can move through such soils.

Pumped at a pressure of approximately 20 psi, Lignosol is injected until it breaks through to the surface.

A dollar a foot.

At many locations, it is reported that good results have been obtained with treatments in which the proportion of Lignosol injected into the soil was considerably less than that suggested by the original experimental work. The practical operating treatment was found to be 25 gal of Lignosol B every 6 ft on both sides of the track. This worked out to 5 tons of chemical for each 100 track-feet at a cost of approximately $ 1.00 per foot.

In the course of the work done on the CNR, it was discovered that the mineralo-

gical classification of the soil did not seem to be a major factor, since sites were chosen without regard to the geology of the terrain. Drainage, says the manufacturer, is of doubtful importance. Successful treatments it is said, have been made in cuts, on level track and in high embankments.

Poor results were obtained where the treatment was made late in the season after the surface of the ground had frozen. However, two of the sites so treated in 1953 began to show improvement two years later.

How Lignosol is applied.

The objective of the Lignosol treatment is, in effect, to form a barrier between the ground water and the frost line. The proper depth at which Lignosol should be injected may be estimated from the date at which the heave first appears and will, in most cases, be found to be between 3 and 4 ft below the surface.

The chemical is applied to the roadbed by means of injection pipes driven to the required depth. Lignosol is then pumped into the ground until it breaks through to the surface. The hole for the pipe is usually started with a lining bar. The pipe, 1 $^{5}/_{16}$ in. in outside diameter, is equipped with a jackhammer bit and a sliding point which prevents it from becoming plugged during driving. After the pipe is driven to the established depth, it is withdrawn 2 or 3 in, opening the sliding point.

Sometimes, it has been found that the soil seems to be completely impermeable and no penetration of the chemical is obtained. In such cases, it has been found, penetration can be achieved by gently raising the pipe somewhat. Care must be exercised inasmuch as the seal between the pipe and the surrounding ground is easily broken. Resistance to penetration can often be overcome by merely twisting the pipe. High pumping pressures tend to break the earth seal around the pipe, although at greater depths they are often necessary. Once the Lignosol has begun to flow into the ground it has been found that a pressure of 20 psi is normally adequate.

Injections are usually made at 6-ft intervals. With this spacing, 25 gal of Lignosol « B » at 40 per cent strength will provide a concentration of 3 per cent (solids basis) in a layer 1-ft thick, assuming a soil density of 100 lb per cu ft and uniform lateral penetration of the chemical. In practice, however, penetration is usually found to be erratic and Lignosol is pumped until the seal around the pipe is completely destroyed or until it breaks through some crevice to the surface.

[625 .216]

Hydraulic buffer for wagons.

Efficiency and economy claimed for design based on experience with aircraft landing gear.

(*The Railway Gazette*, October 11, 1957.)

The design of the Dowty hydraulic buffer is derived largely from those of various hydraulic shock absorbers for aircraft landing gear, and based on experience therewith. Although the problem of arresting the motion of a freight wagon with the minimum of shock is basically similar to that of absorbing as quickly and as smoothly as possible the landing impact of an aircraft, the railway hydraulic buffer must be low enough in cost to justify its use in large quantities and must continue to function efficiently for several years with the minimum of attention.

Figure 1 shows how these problems are being dealt with in the Dowty unit. The shank of the buffer head which forms the piston is screwed and pegged to the head, so forming a rigid attachment, but allowing a standard shank to be used with alter-

Test rig using electronic strain gauge equipment.

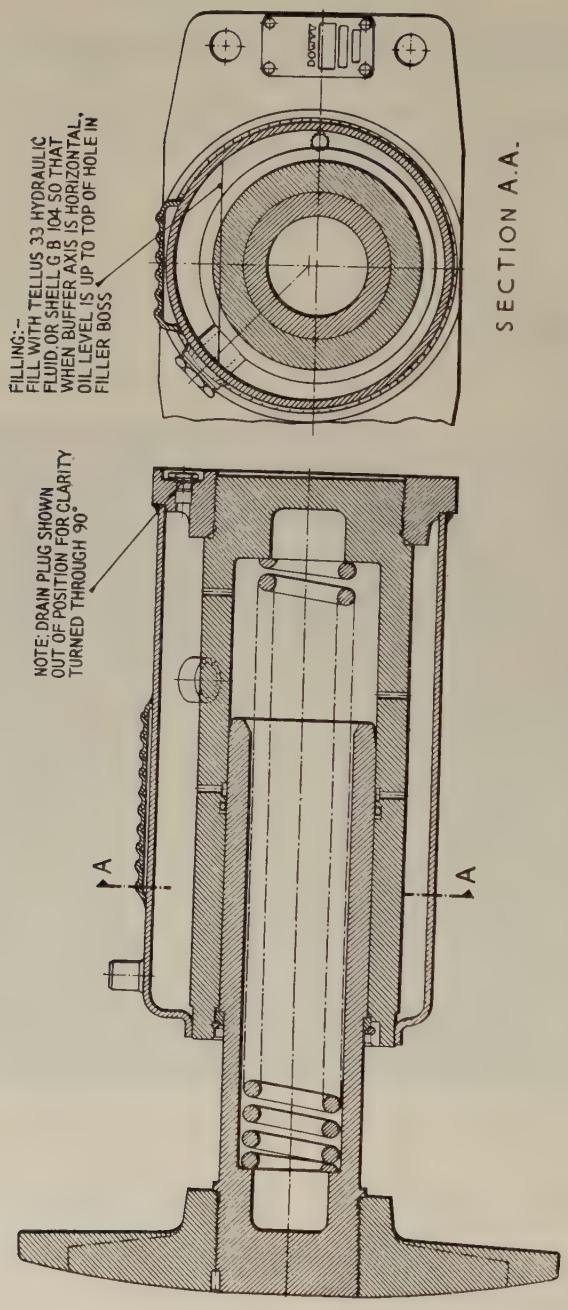
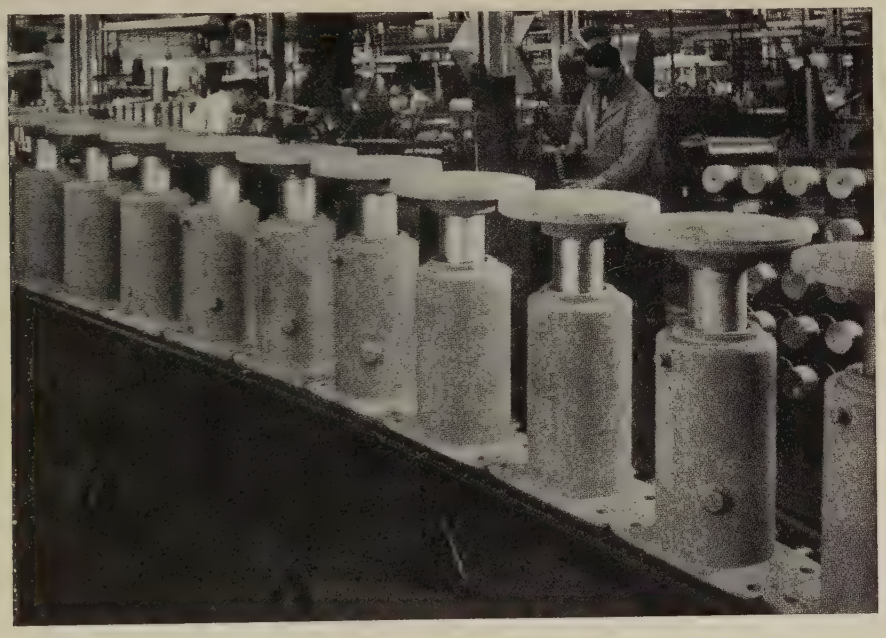


Fig. 1. — Sectional arrangement of hydraulic buffer, showing reservoir and filling plug.

native heads. Manufacture of these components is considerably facilitated and cheapened by the use of two parts. In a similar way and for similar reasons the cylinder in which the piston slides is also screwed into the rectangular mounting flange. A conical seating is provided for the cylinder and to ensure that no leakage occurs at this joint an « O » sealing ring is trapped between the joint faces.



Hydraulic buffers moving to despatch bay after pressure testing.

Hydraulic reservoir.

Surrounding, and extending for the length of the cylinder, is the hydraulic reservoir. This is a solid drawn tube, welded to the back plate and shrunk on to the cylinder at the front end. The tube is mounted eccentrically to the cylinder, with the wide section of the annulus at the top to form an air cushion chamber. At 45 deg. to the vertical axis is the filler plug boss; this position automatically prevents overfilling and so maintains the correct volume of air.

A single low-rate recoil spring is carried inside the piston. This spring is made from ground bar, operates at a low stress range, and has practically unlimited life. The outstop for the piston is provided by a shoulder on the piston which makes contact with a split abutment ring fitted in a recess at the front of the cylinder; the split ring is retained by a stainless steel circlip.

Sealing of piston.

Sealing of the piston against leakage is obtained by the fitting of a synthetic rubber « O » ring, backed up by a rectangular section nylon ring in the same groove. To ensure that this seal is not subject to high pressure, a high pressure leakage groove, connected by drilled holes to the reservoir, is placed on the pressure side of the seal.

The surface of the piston is chrome plat-

ed and polished and operates with a diametral clearance of .004/.006 in. in the cylinder. The exposed portion of the piston attached to the buffer head is reduced in dia. to prevent contact with the cylinder bore; in addition the outstop ring acts as a wiper.

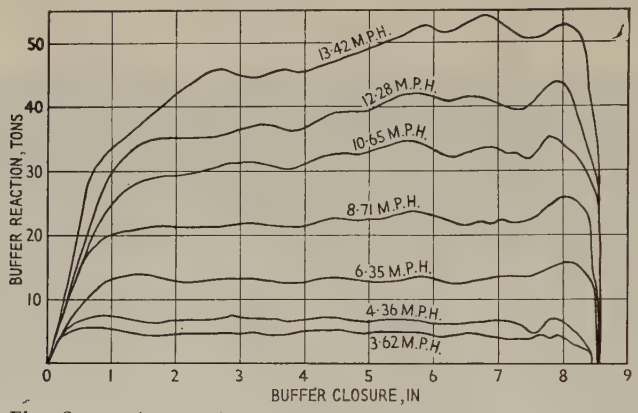


Fig. 2. — Automatic variation of resistance to speed of impact between Dowty hydraulic buffers.

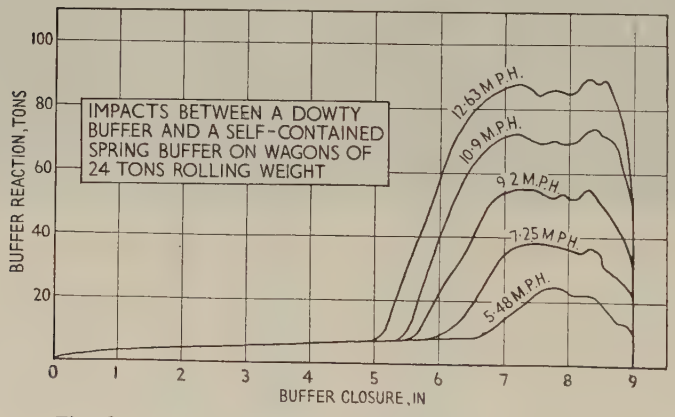

IMPACTS BETWEEN A DOWTY BUFFER AND A SELF-CONTAINED SPRING BUFFER ON WAGONS OF 24 TONS ROLLING WEIGHT
BUFFER REACTION, TONS
BUFFER CLOSURE, IN
12·63 M.P.H.
10·9 M.P.H.
9·2 M.P.H.
7·25 M.P.H.
5·48 M.P.H.

Fig. 3. — Reaction of impact between hydraulic and self contained spring buffers.

Action on impact.

When an impact on the buffer head forces in the piston, oil is discharged from the cylinder through a series of drilled holes into the reservoir. The resistance of the buffer to closure is obtained from the restriction to flow through the holes, the amount of restriction being proportional to the speed of flow. As the piston approaches the end of its stroke some of the holes are covered, thus providing an increased resistance where it is most required.

When the oil is forced through these small orifices the pressure energy is dissipated as heat and not just stored up as in a spring buffer, to be released in the form of a violent recoil.

This feature of automatic variation of buffer resistance according to the speed of impact, which is clearly shown in the performance curves (fig. 2 and 3), is due to the fact that resistance to flow through an orifice increases as the square of the fluid velocity in exactly the same way as the force of impact increases as the square of the wagon speed.

When the fluid is displaced from the cylinder into the reservoir, the air, which is at atmospheric pressure, is compressed slightly. This pressure is used to return the oil to the cylinder on recoil. Excessive speed of recoil is prevented by the flow resistance of the ports into the cylinder.

Durability.

The buffer is made throughout in high-grade steel of robust proportions, but without excessive weight. Development testing included many thousands of shunts over a range of speeds and wagon weights and also a considerable amount of side loading with impacts up to 3 in. out of alignment. Fluid leakage both on test and in service has been very slight, this being largely due to the absence of any internal pressure in the buffer in the normal position. The fluid capacity is 10 pints, which is 1 1/2 pints above that required to fill the cylinder. Tellus 33 or Shell 104 are the makers' recommended oils.

[656 .212 .5 (47)]

Marshalling technique in the Soviet Union,

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1. Special marshalling conditions in the Soviet Union.

All large Railway Administrations have to make considerable efforts to organise the making up and shunting of the trains. It is only possible to make the freight wagons converge at certain points on the system, the marshalling yards, if these have a sufficient capacity. The large capacities involved make mechanisation of the technical operations essential and encourage their automatisation. The great importance of a highly developed marshalling technique is well recognised in the Soviet Union; the large marshalling yards are already mainly mechanised and their automatisation is on the agenda. So much we can learn from the study of substantial specialised publications, the bibliography of which given further on is only a small extract, selected more or less arbitrarily. Important works by Soviet authors are also available in German translations [17] [18]. But such studies of the technical literature are considerably deepened if one has a chance to study the development of marshalling technique in the yards.

During the summer of 1956, in the framework of scientific-technical collaboration the author had the opportunity of visiting certain marshalling yards in the Soviet Union and exchanging views with eminent representatives of the Railway Administration, as well as of the research and study institutes on topical questions affecting marshalling technique. The present article is intended not only to give a brief review of the development of marshalling technique in the Soviet Union but also to indicate the problems which the Soviet railway engineers are trying to solve.

In this connection, the special conditions in which Soviet railwaymen work must not be forgotten. There are first of all the well known climatic conditions, with their low temperatures and heavy falls of snow, which are frequent and prolonged in the north and east of the country. Then there is the vast scale of different weights of wagons to be shunted, from the empty four wheeled wagon weighing about 7 t [24] to the loaded six axled wagon weighing some 127 t (8). Only a very small proportion of the wagons are equipped with hand brakes, so that these do not enter into the technique of marshalling. All the new wagons and many of the old ones are equipped with automatic couplings with centre buffer; in certain regions only wagons with automatic couplings are allowed; in the others, the wagons will all be so equipped by the end of the present five year plan. It has been decided to equip the goods wagons with roller bearings. The carrying out of this step will naturally take some time.

2. The mechanised humps.

The main humps of the marshalling yards are always one of the most important working points. It is at these very heavily loaded points that mechanisation first becomes essential and brings the greatest advantages.

2.1. *Track layout at the gravity humps.*

Between the tracks of the entry ladder tracks and the head of the shunting ladder

tracks, there is often a fairly long intermediate section (neck) with two entry tracks. This section is useful as it makes it possible to reach the level of the hump without having to raise the entry sidings themselves. In addition, this intermediate section facilitates the work of the men responsible for uncoupling who are hindered by the points at the end of the entry ladder tracks. For some time, this intermediate section has been found to be a very useful reserve when it is question of extending the sidings of the entry ladder tracks. This problem is a topical one in the Soviet Union because with the possibility of developing considerable tractive efforts by the use of Diesel or electric locomotives, the very heavy trains now weigh as much as 3 000 to 4 000 t and in the future will weigh 7 000 to 8 000 t. The present sidings, 720, 850 or 1 050 m long will then be insufficient to take complete trains [3] [11]; they will be at least 1 250 m long. These problems are eased by the introduction of wagons having a high weight per linear metre. In addition to the usual covered wagons of 22.7 t tare and 60 t loaded weight, i.e. having a weight per linear metre of 82.7/13.92 = 5.94 t/m; for some time, they have been building six-axled wagons with a tare of 31.6 t and 95 t load, i.e. a weight per linear metre of 126.6/16.4 = 7.72 t/m [8]. When such wagons are used, without altering the length of the sidings the weight of the rakes can be increased by 7.72/5.94 = 1.3 times. Compared with the old two axled wagons, the increase is still greater.

The two tracks of the intermediate section between the entry ladder tracks and the hump are sometimes connected together immediately in front of the hump, so that the spreading out of the sidings towards the shunting ladder tracks starts from a single main track, which simplifies the brake installations. The shunting sidings themselves are strictly grouped together as a ladder track, so that beyond the final braking stage, there are not more than 6 to 8 sidings [1] [13] [19]. The brake stages are generally two, the first on the main track of the ladder track, the second beyond the points where the ladder tracks open out. In view of the great length required for track brakes, which will be dealt with in paragraph 2.3, there are very severe restrictions on the layout of the tracks in plan, because the track brakes must be laid on straight sections.

At the heads of the ladder tracks, symmetrical 201 — 1 : 6 switches are often laid with a length of 17.37 m [2] [17].

2.2. *The longitudinal profile of the gravity humps.*

To find the most favourable longitudinal profile for gravity humps, much attention has been given in the Soviet Union to the determination of the running resistances. In particular, a thorough study has been made of the resistances at very low temperatures [9] [20]. In the instructions concerning the projects [2] [5], detailed indications are therefore given about the running resistances of very free running wagons, free running wagons and poor running wagons at normal temperatures (+5° and over) and for several ranges of low temperatures (down to minus 40° C). There is also a differentiation between currents of wagons composed for the most part of loaded wagons and those consisting of a mixture of loaded and empty wagons. The resistances of the poor running four-axled wagons are sometimes definitely greater than those for the two-axled wagons. At low temperatures, hot oil is poured in the boxes shortly before shunting, which restores the running resistances to the values corresponding to those at normal temperatures [20].

When taking air resistance into account, the fact that in general extremely low temperatures and the strongest winds in the most unfavourable direction do not occur in the same season is taken as a basis. The resistance due to track installations, which is 2 $^{o}/_{oo}$, is only applied over the length of the point and frog (for about 10 m altogether) so that each track installation only represents a loss in height representing the energy of 20 mm [2]. As far as the resistance due to curves is concerned, on the average this is based on a radius of 700 m [14] for the four and two axled wagons.

Bringing the trains up to the hump is simplified when the entry sidings are not arranged on the level followed by a slope to reach the top of the hump, but when there is a slight down slope of 2 to 2.5 $^{o}/_{oo}$ between the entry ladder tracks and the hump. This consideration is of particular importance in the case of the extra heavy trains of the future.

In general, at the present time, in the Soviet Union, the profile used for the shunting sidings includes a short acceleration section on a slope of about 40 $^{o}/_{oo}$, followed by a fairly long slope of 15 to 20 $^{o}/_{oo}$, in which the actual zone of the points is on a slope of 3 to 4 $^{o}/_{oo}$. This profile helps trouble-free shunting since the wagons do not get up any excessive speed. From the point of view of the output, it is better to have a profile which includes a fairly long slope of 50 $^{o}/_{oo}$ and more to speed up the wagons, a short intermediate slope of 15 $^{o}/_{oo}$ where the brakes at the foot of the hump are sited, and a level section for the points or with a slight slope (1 to 1.5 $^{o}/_{oo}$). This profile will be used for the new high capacity installations.

The shunting sidings are generally laid on the level so that it is not possible to do without some means for closing up the rakes. The value of a slight slope in the first one third of the shunting sidings is recognised. During a large scale trial, we were able to observe the closing up of the rakes by the use of a 35 HP caterpillar tractor. This operation is greatly facilitated by the wide space between sidings, which is 5.3 m and allows of great manœuvrability for the tractor. When the tractive effort of the engine in the direction of shunting is insufficient to start a group of wagons moving, a part of this group was set back a little and then pushed forward at a low speed by the tractor to overcome successively the starting resistances of a long rake. The tractor is manned by a driver and a second man who couples and uncouples the couplings of the wagons. The question of consolidating the track on which the tractor runs had to be solved. On non-consolidated ground, it breaks up the earth to some depth. If the ground is covered with heavy timbers or concrete slabs, there is a risk of reducing the adhesion of the tractor tracks. There are no marshalling yards in the Soviet Union on a continuous slope. They are however closely studying all the information relative to experience obtained in this connection in other countries, so as to profit if needs be by the advantages of this type of yard.

In the shunting yard a special braking method is used, the wagons not being spread out at the end of the ladder tracks but allowed to continue running as far as possible, so that the sidings are filled up from the bottom end. To do this it is necessary for the sidings to have a longitudinal profile specially designed with this object in view.

Changes in the gradient are rounded off at a radius of 250 m.

2.3. *The track brake.*

The core of the mechanisation of a marshalling yard is the use of powerful track brakes. Besides trials of telecontrolled shoe type brakes, the Soviet engineers have paid particular attention to clasp type brakes. The type 39 cam brakes previously used are still in service, but are being replaced more and more by the types 40 or 50 clasp type brakes. These two forms of brake have been the subject of detailed descriptions [17] [18]. The type 40 is being reinforced when general overhauls are carried out (40 U), or replaced by the type 50 which is of more robust construction. All these brakes are two-stage braking equipment which do not work automatically as a function of the weight, in other words the braking effort is not specifically adapted to the weight of the wagon. When braking an 80 t wagon, the specific braking effort is between 0.038 and 0.058 [2], in other words 1 m braking length destroys a height representing the energy equal to this figure. A gravity hump of 4 m high therefore requires track brakes having a total length of $4/0.058 = 59$ m to $4/0.038 = 105$ m according to the type used.

As the specific braking effort for the future six-axled wagons will be still lower

than the above figures indicate, it is of interest to devote time to the designing of automatic brakes working as a function of the weight [5]. We were shown in service the prototype of a brake of this type (*Ratnikow* type).

The types 40/50 brakes are noted for their great reliability. Whereas the 39 brake only slowed down about 2 million axles between general repairs, the type 40 will brake 5 million under identical conditions, the type 40 U 7 millions and the type 50 up to 10 million. When sited in such a position that all the wagons shunted run over it, a brake of this type will remain in service for about 4 years, and in the lower braking position, where it gets less use, 8 to 10 years. It is true that during this period, the parts really subject to friction, the brake jaws, are replaced several times in service [18]. When a general repair is necessary, the track brakes, which weigh about 20 t (type 50) are taken up by means of a heavy revolving crane. The track is only blocked for 5 to 6 hours for this purpose.

The types 39, 40 and 50 track brakes are operated by compressed air, the valves being controlled electrically from the signal box. The compressed air is also used on the gravity hump to operate the points (see paragraph 2.4) and for getting rid of snow. For this purpose, there is usually a jet near the points to which a compressed air pipe with a nozzle is connected. At the entry points, which are the most heavily loaded, a network of tubes is fitted under the blades, with 2×6 nozzles worked either by a valve near the points or, more recently, from the signal box. As the snow is generally dry snow, the jet of air works satisfactorily.

The multiplicity of the possibilities of using compressed air has so far kept Soviet engineers from using hydraulic operation of the track brakes. This latter method has the advantage of obeying the control impulses very accurately, whereas the gears with compressed air have slightly more inertia. This advantage has not escaped the notice of Soviet technicians and it is likely that with the development of automatic control of the brakes, it will be impossible to avoid using this method; consequently at the present time hydraulic control is under study.

The track brakes are operated by employees stationed respectively near the upper and lower braking positions. As far as the latter is concerned, the installation of an elevated post in the middle of the ladder tracks gave less satisfactory results than two posts at the sides which had a better view. As each stage of brakes consists of two or three sets of apparatus which are separately operated, very carefully adjusted braking is possible. Trials are in hand for using automatic control. It is proposed first of all to use semi-automatic control, with which the operator records the desired speed on leaving the equipment and the weight of the wagon in three steps on push button scales, and the brake is released automatically when this speed is reached. To measure this, the rail is divided into several sections electrically isolated one from the other. The speed can then be measured by using electric circuits. It is a question however if the isolation can be maintained on the brake with the accumulation of brake dust. Use is also made of contacts fitted in the brake itself and worked by the wheel. To get complete automatisation, it will also be necessary to measure the weight of the vehicle, before it reaches the apparatus. The operation which seems most difficult to the Soviet engineers is the measurement of the distance to be travelled beyond the brake. When the wagon has to travel as far as another at rest on the shunting siding which it must only reach at a moderate speed, it is possible to measure the distance to be travelled. But there is some doubt about this when the first wagon is still moving and the distance between the brake and this wagon is constantly varying. The collecting of the three measurements : weight of the wagon, speed and distance to be run in a calculating machine and the determination of the shunting orders required presents no fundamental problems.

As regards the difficulties already reported in paragraph 2.2 of closing up the wagons on the shunting sidings and filling in

gaps, attempts have been made to overcome this in the Soviet Union by installing a third braking stage on each siding, in the form of either short type 50 brakes, or automatic equipment working as a function of the weight, about 5 m long. This stage of braking is then intended to brake the wagons to a stop as far as possible when they have reached their destination.

2.4. *The shunting posts.*

High shunting speeds are only possible when the points are suitably equipped. The clearest are those with track diagrams, in which the levers are sited in the topologically correct place on the siding plan. When the number of successive wagons is fairly high, individual control of the points presents difficulties and it is then of interest to adopt route control levers. As a third stage, it is possible to make use of a recording of all the routes corresponding to the shunting of a train. The objection sometimes made to recording the routes is that it makes it difficult to make any alterations during shunting.

The marshalling note used currently in Germany is unknown in the Soviet Union. The « operator » in the shunting box works from a list something like our stock bordereau. He announces by loud-speaker the different shunting movements to the satelite posts and pointsmen, and himself operates the first brake, and in certain cases the first set of points as well. The brake operators in the satelite posts also operate the sets of points in their section. The brake levers and lever controlling the points are sited besides each other on the desk. The shunting speeds reached with this method of work are considerable (1.2 to 1.5 m/sec); when large groups of wagons are being shunted, they are even higher (2 m/sec).

The devices controlling the points by compressed air take 0.5 sec to operate (0.9 sec with the check). The points equipped in this way have a simple keyed balance-bar which is a sort of articulated lock. The other sets of points controlled by electric motors have no keyed balance-bar, but a device controlling the position of the points is included in the controls.

2.5. *Communications during shunting operations.*

Light signals are used as marshalling signals. In addition to the signals « marshalling authorised » (white light) and « marshalling forbidden » (blue light), there are shunting signals on the hump with three indications : « shunt at high speed » (green light), « shunt at reduced speed » (yellow light) and « stop » (red light). The red light also includes an additional signal consisting of the Russian letter N (nasad = back), which orders reversed running. The shunting signals are operated from the shunting post and sited all along the entry lines to the hump, with repeaters.

With this organisation, the yard foreman, who moves along the train, has difficulty in speaking to the driver. In addition, visibility of the signals is not very satisfactory in bad weather. The shunting locomotive is therefore equipped with acoustic signals worked by the track circuit. The transmission of coded current on the locomotive makes use of devices similar to those used for optical signals in the driver's cab when running on the line. The track circuits are operated by the foreman, there being several posts with push buttons along the track. The Soviet railwaymen are still not completely satisfied with this organisation and hope to get better results by using radio. Ultra-short wave equipment is available for both fixed posts and use on the locomotives. In the case of portable sets, an apparatus is being studied which will probably work by means of transistors. Intensive use is made of loud-speakers.

We were shown as a curiosity a funicular installation for transporting the waybills from the arrival to the departure office. Small trucks operated by a motor run over two carrying cables which also supply the current. In bad weather, this equipment is troublesome.

As regards the lighting, there is nothing special to report. High towers are often seen for lighting by means of floodlighting.

3. The development of shunting by fly shunting rakes.

The technicians of the Soviet Union have not confined themselves to perfecting gravity marshalling and its mechanisation. They are very interested in fly shunting, which is the only shunting method in a great number of small and averaged sized yards, and is even being used in large yards to make up trains from the draw out siding. It should be noted in this connection that no classification by station is used in the ladder tracks and the rakes are formed at the ends of the shunting sidings.

Now, various inventors of railway services have suggested and successfully applied different fly shunting methods which have certain advantages compared with the system of shunting single units.

In the *Karachkevitch's method of fly shunting by multiple groups,* a group of wagons that have been previously uncoupled into the desired units is set in motion by the locomotive. When the group is started, it is first of all moved as a block but then split up by means of the brake skid shoes, which are introduced from the side by a pole under the second wagon of the group and the succeeding wagons, then thrown out by the frogs (similar to the Büssing apparatus). By inserting shoes several times, it is possible to get sufficiently large gaps between the wagons of the group for it to be possible to operate the points between them [21].

With *continuous fly shunting* on the Archipov and Loutchkow methods, the driver speeds up the group of wagons till the speed is great enough for the first wagon which has already been uncoupled. Then he brakes the rake slightly from the locomotive. The braking effect on the group of wagons gives the shunter a chance to uncouple the second wagon. Then the driver starts a second braking stage which is used to uncouple the third wagon. The speed of the rake being shunted is reduced in this way in several stages until it comes to a stop or has to be speeded up again. The method requires very close collaboration between the foreman, who gives the shunting signals, the driver and the shunter [7]. To throw out the screw couplings, the shunter generally uses duralumin poles about 1.80 to 2 m long which weigh 4.5 to 5 kg and give better results than steel poles.

With the Gourjev *method of fly shunting in series,* the rake to be shunted is slightly braked after the first wagon has been sent off but without waiting for it to stop. Starting from this state of movement, the rake is again accelerated and then braked. During these operations the speed varies between 12 and 4 km/h [6] [21]. The special feature of this method lies in the fact that the driver never closes his regulator. This remains open all the time. The different degrees of braking are obtained by means of the auxiliary brake. To begin with the drivers were afraid that this method of operating would lead to excessive wear : these fears have been proved groundless. The locomotives are equipped with profiled brake shoes which act not only on the surface of the tread but also on the flange.

It is obvious that this method of working can only be used with very experienced shunting staff. But they also require particularly favourable gradient conditions in the draw out sidings, for example a slope of 3 to 4 $^{o}/_{oo}$ which has to be laid out very carefully [25].

If the draw out siding has a continuous slope of 3 to 3.5 $^{o}/_{oo}$, it is possible to leave it to gravity to bring the rake to the knocking off point, provided it has previously been speeded up to the correct speed by means of a shunting locomotive [12] [26] [28]. The locomotive then only has to overcome the starting and acceleration resistances, and can leave the draw out siding through a branch line to go and pick up the next rake and bring it to the draw out siding. This method has been suggested and used by Tchernelewskij. Here again the plan and longitudinal profile must have suitable features [25]. A longitudinal profile which is particularly suitable for this method is one with slopes increasing to-

wards the shunting or knock off point, in other words a track which is incurved in the longitudinal section.

4. The lessons to be learnt from the experience of the Soviet Union.

After this examination of marshalling technique in the Soviet Union, it is only logical to compare it with the position in Germany and draw the necessary conclusions for our own evolution. The following remarks do not pretend to be complete and are limited to bringing out certain special problems.

4.1. *Wide angle track installations (with wide openings).*

The spreading out of the sidings beyond the hump need not be so long if wide angle track installations (with wide openings) are used. The Soviet engineers have shown themselves very interested in the switch with an outer curve of 49 — 215 — 1 : 4.8 designed in Western Germany [16]. This or a similar type is also going to be introduced on the Deutsche Reichsbahn.

4.2. *Running resistances.*

A knowledge of the running resistances is absolutely essential for a thorough study of gravity humps. The introduction of four-axled wagons and the intention to use roller bearings on the wagons makes it necessary to measure the corresponding values of the resistance under all atmospheric conditions. The trials are in fact an urgent matter because only when they have been completed will it be possible to get out the new directives for designing the installations. The measurements obtained in the Soviet Union make possible invaluable comparisons, but do not make it unnecessary to carry out such measurements in Germany also.

4.3. *Track brakes.*

An important factor in designing track brakes is the question of their effect on the structure gauge. The Soviet Railways will not allow any fixed track component to be more than 90 mm above rail level. The usual measurements in Germany (120 mm on the outside and 130 mm on the inside), definitely exceed this figure. The department designing brakes would like to use higher values, but have met with uncompromising resistance from the rolling stock builders. It appears necessary to conclude an international agreement about the height to be used in the future, in order to allow of the free exchange of wagons. In the case of the track brake, the height cannot be too great.

The evolution in the Soviet Union is definitely from the track brake which must be set for the lightest wagon towards automatic braking as a function of the weight. Owing to the fact that heavy wagons must also be expected to run in Germany, it is necessary to perfect still more the type of brake whose braking force is automatically a function of the weight [15]. In this connection, it is not essential for the automatic braking as a function of the load to be obtained by mechanical transmission. The separation of the operations controlling the braking effort, the first being controlled by a balance bar in front of the brake, and a regulator seems to be a promising idea.

It appears sensible to begin by applying hydraulic control to track brakes, because this is the only way in which it is possible to get the very carefully adjusted regulation which automatisation requires.

4.4. *The shunting cabin.*

Shunting cabins should be made in the form of cabins with track diagrams. It is not adsolutely essential in this connection to provide a route recording device capable of covering a whole train. On the contrary it appears sufficient to use a device which can record a few movements only.

4.5. *Radio for marshalling.*

It is an urgent matter to improve communications by means of ultra-short waves. Equipment, which is easy to carry about, designed for shuntsmen, is particularly required.

4.6. *The technique of knocking off or fly shunting.*

The example of Soviet railwaymen in the field of fly shunting railway wagons should be studied and imitated in Germany also. Carefully designed shunting sidings for such movements will in many cases make it possible to avoid costly alterations with very high gravity humps.

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1958 **621** .335 (44)
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Dual frequency electric locomotives for French Railways. 800 words.)

1958 **621** .431 .72 (731
The Locomotive, February, p. 26.
Diesel locomotive experience in the United States. (2 300 words & fig.)

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A motorcar transporter for Anglo-Continental service. (600 words & fig.)

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1956-1957. — Progress in railway mechanical engineering. (3 000 words & figs.)

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SHEDD (T.). — D & H cycles M/W work. (2 600 words & figs.)

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PRR speeds up car cleaning. (1 200 words & figs.)

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ARKLE (E.W.). — **Railway management.** (3 600 words.)

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Fully automatic junction signalling. (1 300 words & figs.)

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Lightweight railbus. (1 200 words & figs.)

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Automatic warning control. (1 200 words & figs.)

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1958 **656** .254 (73)
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New ideas spur RR communications. (2000 words & figs.)

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More mechanization for M/W works. (2 400 words & figs.)

1958 **656** .2 (73)
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ELMER MONROE (J.). — **1957 Review of railway operations.** (9 000 words & figs.)

1958 **621** .438 (73)
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U.P. gets bigger gas turbines. (1 200 words & figs.)

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1958 **625** .285 (485)
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BINGHAM (S. H.). — **Swedish lightweight train.** KLL prototype 1 020 HP seven coach set with unusual features. (1 500 words & figs.)

1958 **385** (09 (51)
The Railway Gazette, January 10, p. 43.
Developments on the Chinese Republic Railways. (1 600 words & figs.)

1958 **625** .13 (492)
The Railway Gazette, January 10, p. 46.
Railway tunnel under Netherlands North Sea Canal. (400 words & figs.)

1958 **621** .431 .72 (41) & **625** .285 (41)
The Railway Gazette, January 17, p. 71.
Diesel-hydraulic trains in Ulster. (1 000 words & figs.)

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The Railway Gazette, January 17, p. 72.
Foundations, piers and superstructure of the Ganges bridge. Design of the well-curbs, wells, piers, and spans and construction of the piers. (1 300 words & figs.)

1958 **621** .33 (42)
The Railway Gazette, January 17, p. 76.
Progress of electrification in the eastern region. (1 400 words & figs.)

1958 **621** .33 (54)
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Electric traction in the Calcutta area. (2 000 words & figs.)

1958 **625** .2 (01
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Investigations into hunting of railway vehicles. (1 600 words.)

1958 **621** .385 (54)
The Railway Gazette, January 24, p. 104.
Remodelling of Ajmer workshops, Western Railway of India. (1 000 words & figs.)

1958 **656** .212 & **656** .22
The Railway Gazette, January 24, p. 106.
Electronic system of vehicle identification. (2 500 words & figs.)

1958 **625** .213
The Railway Gazette, January 31, p. 130.
Evaluation of riding of passenger coaches. (1 200 words & figs.)

1958 **625** .232 (42)
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Second class prototype open saloon for British Railways. (600 words & figs.)

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General-purpose locomotives for B.R. (3 000 words & figs.)

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Freight-transfer power, British Railways. (3 200 words & figs.)

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Powerful multi-car train in U.S.A. (800 words & figs.)

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Twin-car trains in Luxembourg. (1 000 words & figs.)

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Fluidin shunting locomotive performance. (300 words & fig.)

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Railway Locomotives and Cars, January, p. 33.
UP 8 500-HP turbines ready to roll. (1 200 words & figs.)

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Railway Locomotives and Cars, February, p. 45.
Old electrification adds new electrics. (1 000 words & figs.)

In Spanish.

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1958 **625** .26
Ferrocarriles y Tranvias, vol. 24-VI, nº 274, p. 161.
SANCHEZ PEREZ (J.). — Un aspecto concreto de la cuestión : « **El factor humano en la productividad de los talleres ferroviarios** ». (1 500 palabras & fig.)

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PUJOL ROIG (M.). — **Contribución al estudio de los aceres nacionales para rodamientos.** (3 000 palabras, tablas & fig.)

In Italian.

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1958 **624**
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POZZATI (P.). — **Reticoli di travi.** (5 000 parole & g.)

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GIANGRECO (E.). — Una **ricerca teorico-sperimentale sullo svergolamento delle travi alte in regime elasto-plastico.** (5 000 parole & fig.)

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1958 **656**
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ANGELINI (A.). — **I problemi dei trasporti terrestri in campo internazionale.** (10 000 parole.)

1958 **385** (09 (45)
Ingegneria Ferroviaria, gennaio, p. 11.
DIREZIONE GENERALE DELLE F.S. — **Uno sguardo alle attività delle F.S. nell' anno 1957.** (40 000 parole & fig.)

1958 **656 .2** (45)
Ingegneria Ferroviaria, gennaio, p. 60.
LALONI (N.). — **Il problema ferroviario italiano e la possibilità di risanare il bilancio delle F.S.** (7 000 parole & fig.)

1958 **62**
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POLSONI (G.). — **Diagrammi : integrazioni ed interpolazioni per l'ingegnere.** (1 000 parole & tabelle.)

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FIORAVANTI (G. L.). — **Il « Talgo » e i suoi derivati.** (3 000 parole & fig.)

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FENELLI (N.). — **Oneri e risanamento del bilancio delle Ferrovie dello Stato.** (3 000 parole.)

1957 **656 .224** (45)
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CONIGLIARO (G.). — **Ripercussioni della reduzione delle classi di viaggio** e degli aumenti tariffari del 1956 sui prodotti del traffico viaggiatori. (2 500 parole & tavole.)

1958 **656**
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I problemi dei trasporti terrestri in campo internazionale. (4 000 parole.)

1958 **625 .212 : 625 . 42**
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di PIERO FRANCO FEA. — **Le Vetture metropolitane su gomma,** contributo sostanziale ai grandi trasporti pubblici urbani. (6 000 parole & fig.)

1958 **621 .335** (45)
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DARD (M.). — Le **elettromotrici bicorrenti** delle Ferrovie dello Stato. (1 600 parole & fig.)

1958 **621 .33** (439)
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La **trazione ellettrica** sulle Ferrovie Ungheresi. (2 000 parole & fig.)

In Netherlands.

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1958 **621 .3**
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KEMPER (K.). — Enige bijzondere vormen van **magnetische versterkers.** (4 000 woorden & fig.)

1958 **691**
De Ingenieur, nr 11, 14 maart, p. Bt 29.
HAAS (A.M.). — **World conference on prestressed concrete** te San Francisco, 29 juli-2 augustus 1957. (5 000 woorden & fig.)

1958 **625 .62** (492)
De Ingenieur, nr 12, 21 maart, p. V. 9.
Het **nieuwe tramwegmateriaal** te Rotterdam en te 's-Gravenhage. (5 000 woorden & fig.)

Spoor- en Tramwegen. (Den Haag.)

1958 **725 .31** (492)
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SCHELLING (H.G.J.). — **Nieuwere spoorweg-stations.** I, II en III. (4 500 woorden & fig.)

1958 **656** (4)
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LANDSKROON (F.P.A.). — De **coördinatie van het Europese vervoer.** III. (2 000 woorden.)

1958 **385** .587

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HOOFTMAN (J. C.). — Doelmatiger werken. I. **Automatisering en produktiviteit.** (2 500 woorden.)

1958 **659** (42)

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JAGER (J. A.). — **Vervoerswerving te Londen.** (2 000 woorden.)

In Portuguese.

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1958 **385** .1

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de BRITO LEAL (C.). — O problema da **situacão financeira** dos Caminhos de Ferro. II-III. (5 000 palavras & tabelas.)

1958 **385** (09 (469)

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MANITTO TORRES (C.). — A **evolucão das linhas** portuguesas e o seu significado ferroviário. *(Continuação.)* (4 000 palavras.)

In Czech. (= 91.886.)

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1957 **621** .332 (= 91 886)

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SOVINSKÝ (D.). — New methods of calculation for **foundations of electric line supports.** (1 000 words & figs.)

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1958 **621** .331 = 91 886

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DAMBORSKÝ (D.). — The putting into service of a **transformer station on the Czechoslovakian Railways.** (3 000 words & figs.)

1958 **625** .143 .4 = 91 886

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LINER (O.). — **Problems of the continuous welded track.** (2 500 words & figs.)

In Serbo-croate (= 91.882).

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1957 **62** (01 (= 91 882)

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